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A Review of Standards of Performance for New Stationary Sources Portland Cement Industry

MITRE Corp, McLean, VA METREK Div

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ABSTRACT

This report reviews the current Standards of Performance for New Stationary Sources: Subpart F - Portland Cement Plants. It includes a summary of the current particulate matter standard, the status of current applicable control technology, and the ability of plants to meet the current particulate matter standard. No changes to the existing standard are recommended, but EPA should continue evaluation of sulfur oxide and nitrogen oxide controls with a view toward incorporating these emissions under the scope of the standard at a later date.

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1.0 EXECUTIVE SUMMARY

The objective of this report is to review the New Source Performance Standards (NSPS) for portland cement plants in terms of developments in control technology, economics, and new issues that have evolved since the original standard was promulgated in 1971. Possible revisions to the standard are analyzed in the light of compliance test data available for NSPS-affected facilities. The review includes the particulate matter mass emission limit for cement kilns and clinker coolers, as well as the opacity standard for these and other sources within the cement plant. The following paragraphs summarize the results and conclusions of the analysis, as well as recommendations for future action.*

1.1 Best Demonstrated Control Technology

The portland cement industry was one of the first industries to have a NSPS promulgated to control their emissions due to the large quantity of particulate matter emitted. The cement kiln and clinker cooler are the primary sources of those emissions. The original standard was based on greater than 99 percent removal of particulate matter from the exhaust streams of the kiln and cooler by fabric filter baghouses. Electrostatic precipitators (ESPs) used at that time were incapable of meeting the new standard. Since that time, ESPs have been improved to the point where they also are capable of

*This report is based on data that were available in November 1978.

controlling emissions from cement kilns to satisfy NSPS requirements. Gravel bed filters and one wet scrubber have been used successfully, in addition to the baghouse, to control emissions from clinker coolers.

There are 49 NSPS affected cement kilns and clinker coolers operating. Data were available on 29 kilns and 20 coolers, all of which were in compliance. Electrostatic precipitators were installed on 12 kilns, baghouses on 16 kilns and 16 coolers, gravel bed filters on 3 coolers, and a wet scrubber was installed on 1 cooler (Data for one kiln compliance test did not include the type of control.)

1.2 Current Particulate Matter Emission Levels Achievable with Best Demonstrated Control Technology

Of the 49 known NSPS-affected cement kilns and clinker coolers, 47 are in compliance with the 0.15 kg/Mg kiln feed (kiln) and 0.05 kg/Mg kiln feed (cooler) emission limits. One completed kiln has only recently been tested and data are not available; and one facility has notified its state authority that it cannot meet the standard. The number of sources with other NSPS-affected facilities is unknown, although there are none that are not in compliance with the applicable 10 percent opacity standard.

The mean emission rate for 29 cement kilns was 0.073 kg/Mg dry kiln feed (range 0.013 to 0.142). There was a random spread of test results within the range of values, indicating that no control or process technology was consistently better at reducing emissions.

The mean emission rate for 20 clinker coolers was 0.024 kg/Mg dry kiln feed (range 0.005 to 0.061). Again, there was no correlation among control, process, and emission level.

There are no data to indicate the effect of time on the emission levels measured. It can be assumed that emissions increase as control equipment deteriorates with age.

1.3 Economic Considerations Affecting the NSPS

The cement industry has been thoroughly investigated by the Council on Price and Wage Control because of its influence on the construction industry. Although the Council concluded that pollution controls are not the most important factor in cement plant closings, it did state that a large increase in pollution abatement costs could influence new construction. This is very important in a period when regions of the U.S. are experiencing a shortage of cement production capacity.

Because of the maximum capabilities of the control technologies and the closeness of many of the compliance tests to the standard, it is recommended that the present level of emissions specified in the current NSPS not be changed.

1.4 Future Additions to the Standard

The portland cement industry generates large quantities of gaseous pollutants, primarily NO_x and SO_2. The sulfur dioxide emissions are reduced approximately 70 percent by sorption in the

process and are incorporated in the clinker, or removed with the collected dust.

Nitrogen oxides, however, are emitted to the atmosphere without control. Using EPA NO_x emission factors, it is estimated that as much as 93,000 metric tons (Mg) of NO_x were emitted by cement plants in 1977. Presently, there are no economically feasible controls for these emissions.

It is recommended that research be conducted to determine the actual cement kiln SO_2 and NO_x emission levels and that the effect of process changes, such as flash calciners, on NO_x generation be determined.

2.0 INTRODUCTION

Section 111 of the Clean Air Act, "Standards of Performance for New Stationary Sources," requires that "The Administrator shall, at least every four years, review and, if appropriate, revise such standards following the procedure required by this subsection for promulgation of such standards." Pursuant to this requirement, the MITRE Corporation, under EPA Contract No. 68-02-2526, is to review 10 of the promulgated NSPS including portland cement plants.

The purpose of this report is to review the current portland cement plant standards and to assess the need for revision on the basis of developments that have occurred or are expected to occur in the near future. This report addresses the following issues:

1. Review of the definition of the present standard.
2. Review of the portland cement industry and the status of applicable control technology.
3. Analysis of the cement plant particulate matter emission test results and a review of the level of performance of best demonstrated control technology for emission control.
4. Review of the portland cement industry economics and projections of new kiln construction.
5. Discussion of cement plant gaseous emissions and control technology presently available.

Based on the information contained in this report, a set of findings is presented and specific recommendations are made for changes in the NSPS. In addition, recommendations are made for R&D studies on gaseous emissions.*

*This report is based on data that were available in November 1978.

3.0 CURRENT STANDARDS FOR PORTLAND CEMENT PLANTS

In accordance with the Clean Air Act of 1973, New Source Performance Standards (NSPS) were promulgated that specified allowable levels of particulate matter emissions from portland cement plants. Any portland cement plant which commenced construction on or after August 17, 1971, became subject to the NSPS.

The NSPS for portland cement plants were originally promulgated on December 23, 1971. On June 29, 1973, the U.S. Court of Appeals for the District of Columbia remanded the NSPS for portland cement plants to the Environmental Protection Agency as a result of questions regarding the standards, in particular opacity standards (40 CFR 60.60). Petitioned by the Portland Cement Association with respect to the opacity standards, the Court of Appeals identified two aspects of the standards as bases for concern: (1) the inherent reliability of opacity standards, i.e. whether measurements of opacity can be made with reasonable accuracy, and (2) the achievability of the opacity standard set for portland cement plants. EPA's response to the remand concluded that the opacity standard is a reliable, valid and necessary standard that meets the requirements of Section 111 of the Clean Air Act, and that the standards other than the opacity standard should not be changed (EPA, 1974). However, EPA did conclude that the opacity standard should be revised. Where the opacity standard had originally been 10 percent for all affected facilities, it was subsequently modified on June 14, 1974, to 20

perce t for cement kilns and 10 percent for all other affected facilities (EPA, 1974). EPA's position was supported by the Court.

3.1 Affected Facilities

The facilities of a portland cement plant that are subject to NSPS are the: kiln, clinker cooler, raw mill system, finish mill system, raw mill dryer, raw material storage, clinker storage, finished product storage, conveyer transfer points, bagging, and bulk loading and unloading systems. Also affected by NSPS are modified portland cement plants (a plant that has undergone a physical or operational change that increases the emission rate of any pollutant regulated by the standard) and reconstructed portland cement plants (those in which the cost of replacement components exceeds 50 percent of the cost of building a comparable new facility).

3.2 Controlled Pollutants and Emission Levels

The NSPS for portland cement plants require the control of particulate matter emissions. As stated in 40 CFR 60.62, no owner or operator of a portland cement plant under construction on or after August 17, 1971, shall discharge or cause the discharge into the atmosphere from any kiln any gases which:

1. Contain particulate matter in excess of 0.15 kg/Mg (0.30 lb/ton) of feed to the kiln, or
2. Exhibit 20 percent opacity or greater;

or discharge to the atmosphere from any clinker cooler any gases which:

1. Contain particulate matter in excess of 0.050 kg/Mg (0.10 lb/ton) of feed (dry basis) to the kiln, or

2. Exhibit 10 percent opacity or greater;

or discharge to the atmosphere from any affected facility other than the kiln and clinker cooler any gases which exhibit 10 percent opacity, or greater.

3.3 Testing and Monitoring Requirements

A performance test of a portland cement plant must be conducted within 60 days after the facility has achieved its maximum production rate and not later than 180 days after its initial startup. Such a test consists of three separate runs of which the arithmetic mean is the result for determining compliance with NSPS. If one of the runs is lost due to forced shutdown, failure of an irreplaceable portion of the sample train, extreme meteorological condition, or other circumstances beyond the operator's control, the arithmetic mean of the remaining two runs may suffice as the performance test result, upon approval by the Administrator.

Test methods to be used to determine compliance with NSPS are:

1. Method 5 for the concentration of particulate matter and the associated moisture content, with minimum sampling times of 1 hour and minimum volumes of 0.85 dscm (kiln) and 1.15 dscm (cooler)

2. Method 1 for sample and velocity traverses

3. Method 2 for velocity and volumetric flow rate

4. Method 3 for gas analysis.

The owner or operator of a portland cement plant subject to NSPS is also required to record the daily production rates and kiln feed rates.

3.4 Regulatory Basis for Any Waivers, Exemptions, or Other Tolerances

Compliance with the mass emission standard is determined by the results of performance tests (Reference Method 5). These tests are conducted only on an affected facility that is operating at a level representing normal operations. Operations during periods of start-up, shutdown, and malfunction are specifically exempted as nonrepresentative operations.

The opacity standard applies at all times except during periods of startup, shutdown, and malfunction. Opacity readings of portions of plumes that contain condensed, uncombined water vapor are not used to determine compliance. Although these exemptions apply to all affected facilities, owners and operators are required to maintain and operate their facilities in a manner consistent with good air pollution control practice for minimizing emissions, even during the exempt periods.

4.0 STATUS OF CONTROL TECHNOLOGY

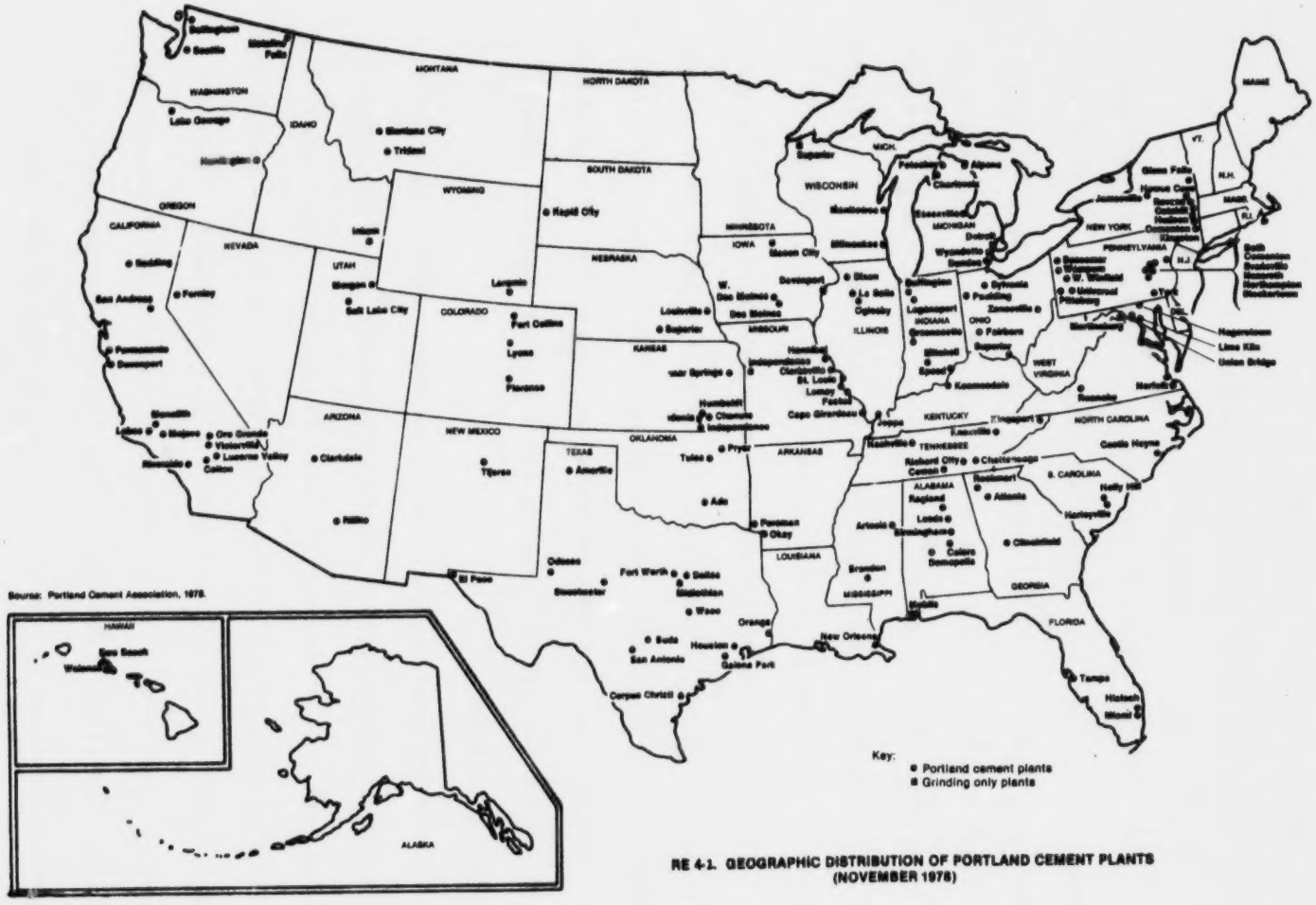
4.1 Scope of Portland Cement Operations

4.1.1 Geographic Distribution

There are currently 53 cement companies producing portland cement in the U.S. The largest producers are Ideal (6.5% of total capacity), Lone Star (6.2%), Martin Marietta (5.1%), and General (5.0%). The 53 companies operate 158 cement plants throughout the U.S. with the largest single plant having a total cement capacity of 2,161,000 Mg per year. The smallest plant has an annual cement capacity of 50,000 Mg (Portland Cement Association, 1978).

The industry also operates plants solely with clinker grinding facilities. These plants (eight in all with a total annual cement capacity of 2,614,000 Mg) use either imported or domestic clinker as feed material and are very important during periods of high demand when imports increase to make up for a lack of domestic clinker producing capacity.

The geographic distribution of the cement plants is shown in Figure 4-1. Cement plants are found in nearly every state because of the high cost of transportation. The actual clinker capacity of these plants is also distributed throughout the U.S., although some regions have little capacity due to a lack of demand. Table 4-1 shows the distribution of clinker production capacity in each EPA Region. The clinker capacity in New England, the Northwest, and Midwest is dwarfed by the capacity of the rest of the country.



Source: Portland Cement Association, 1978.

RE 4-1. GEOGRAPHIC DISTRIBUTION OF PORTLAND CEMENT PLANTS (NOVEMBER 1978)

TABLE 4-1

PORTLAND CEMENT CLINKER PRODUCTION CAPACITY

EPA Region	Clinker Capacity[b] (10^3 Mg/yr)	New Kilns 1972-1978[a] No.	New Kilns 1972-1978[a] Capacity (10^3 Mg/yr)[b]	Announced Growth[c] No.	Announced Growth[c] Capacity (10^3 Mg/yr)	Announced Growth[c] Year[a]
I	None	None	-	None	-	-
II	4,248	1 Dry	490	None	-	-
III	12,159	3 Dry	1,602	None	-	-
IV	14,852	7 Dry	3,883	1 Dry[d]	100	79
		4 Wet	1,744	1 Dry[d]	1,361	81
V	13,337	9 Dry	4,215	1 Dry	518	80
VI	11,889	2 Dry	753	1 Dry[d]	499	79
		3 Wet	785	2 Dry	236	79
				1 Dry[d]	726	80
				1 Dry	205	80
				1 Dry[d]	907	NA
VII	10,431	4 Dry	1,123	1 Dry	131	78
				1 Dry	603	80
VIII	3,942	1 Dry	509	1 Dry	122	79
		3 Wet	863	1 Wet	81	79
IX	11,789	2 Dry	720	3 Dry	483	79
		1 Wet	441	3 Dry	1,406	NA
X	2,333	None	-	1 Dry[d]	454	79
TOTAL	84,980	29 Dry	13,295	19 Dry	7,751	
		11 Wet	3,833	1 Wet	81	

NA = Not Announced

[a] Completion Year
[b] As of December 31, 1977
[c] As of November 15, 1978
[d] New plant

Source: Portland Cement Assn., 1978.

Although many areas of the country are presently experiencing cement shortages and delays, announced capacity increases in these areas are still small. Table 4-1 also shows the trend toward new construction of dry process kilns. During the last 7 years, nearly three times as many dry process kilns as wet process kilns have been built (29 dry vs. 11 wet), for an increase in clinker capacity of 17,128,000 Mg/yr (13,295,000 dry vs. 3,833,000 wet).

4.1.2 Technological Trends in Production

The portland cement industry is very energy intensive with energy costs accounting for approximately 40 percent of the cost of cement. A number of new innovations have been made in the production process to increase energy efficiency. The dry process can be twice as energy efficient as the wet process. The dry process uses driers or combined drying/grinding units to reduce the raw material free moisture content to less than 1 percent. The wet process is very similar to the dry process except that water is added to the raw materials before or during grinding so that the kiln feed material is a slurry. Energy savings are realized immediately because there is no water to evaporate from the feed material. For this reason, almost all new and planned construction will use the dry process. Additional large savings can be realized by using preheaters, especially suspension preheaters. Table 4-2 shows the energy savings attributable to the various new technologies.

These process changes have both positive and negative effects on particulate emissions. The replacement of wet process units with dry

TABLE 4-2

ENERGY CONSUMPTION OF PORTLAND CEMENT MANUFACTURING PROCESSES

Process	Energy Consumption (10^6 BTU/ton)	Energy Reduction Over Average Current Practice (%)
Wet Process		
Long Kiln (average current practice)	5.94	---
Calcinator and short kiln	4.68	26.9
Preheater and short kiln	3.60	43.8
Dry Process		
Long Kiln (average current practice)	4.68	---
Suspension preheater and short kiln	3.15	50.8
Grate preheater and short kiln	3.42	46.6

SOURCE: Ketels et al., 1976.

process units increases emissions, particularly in the grinding, mixing, blending, storage, and feeding of raw materials to the kiln. The suspension preheater, on the other hand, tends to decrease particulate emissions due to its multicyclone construction. It also ensures more thorough contact of the kiln exhaust gases with the feed material which may increase sorption of sulfur oxide from the exhaust on the feed.

4.2 Production of Portland Cement

There are four distinctive steps in the production of portland cement:

- Quarrying and crushing of raw materials
- Grinding and blending raw materials
- Clinker production
- Finish grinding and packaging.

These four steps are depicted in Figure 4-2. The production of portland cement begins with the quarrying of raw materials. In the initial step, cement rock, limestone, clay, and shale are generally mined from open pit quarries at or near the cement plant. The large rocks are crushed to a final size of 2 to 2.5 cm and stored for future use in piles or compartments.

The second production step is the preparation of raw materials for feeding to the kiln (pronounced "kill"). The raw materials are ground to approximately 200 mesh either before, during, or after blending. Either the dry process or the wet process is used. In the dry process, heat for drying is provided by direct dryer firing of

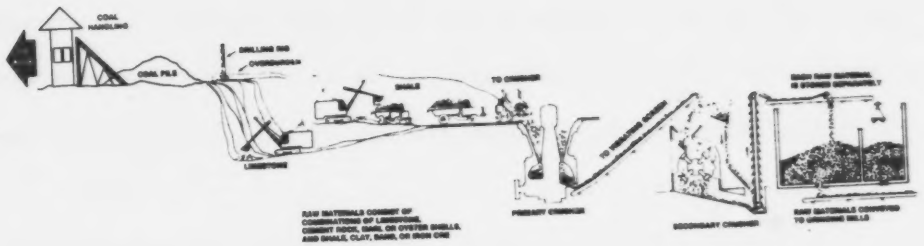


FIGURE 4-2A.
QUARRYING AND CRUSHING OPERATION

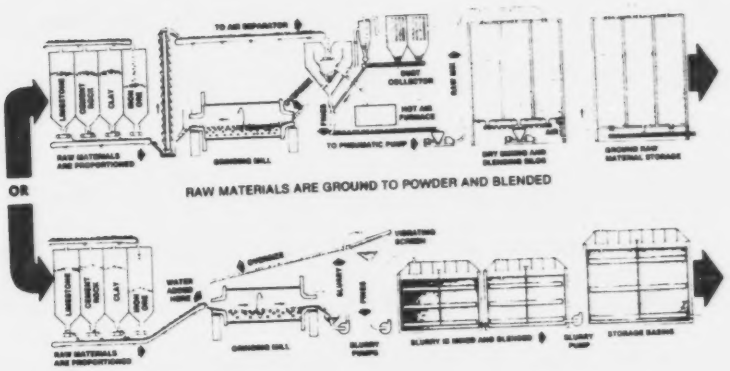


Figure 4-2B
GRINDING AND BLENDING OPERATIONS

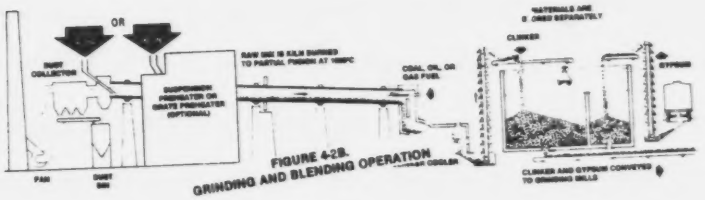
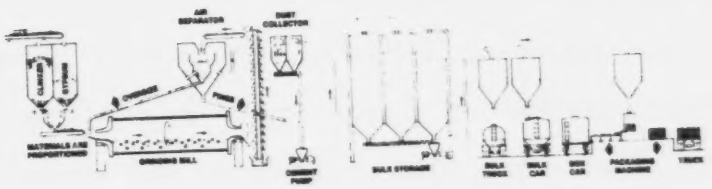


FIGURE 4-2B.
GRINDING AND BLENDING OPERATION

FIGURE 4-2C.
KILN OPERATION



Source: U.S. Department of Health, Education, and Welfare, 1967.

FIGURE 4-2D.
FINE GRINDING AND PACKAGING OPERATION

FIGURE 4-2. PRODUCTION OF PORTLAND CEMENT

coal, oil or gas, separately fired furnaces, or hot kiln exhaust gases. The finished finely ground raw material is then conveyed to blending, homogenizing, and/or storage silos. Kiln feed is then withdrawn from the silos.

In the wet process, the raw materials may be proportioned prior to grinding or individual raw material slurries may be blended after grinding. The finished slurry used as kiln feed may be 30 to 40 percent water or it may be dewatered to approximately 20 percent water and fed as a filter cake.

The third step, clinker production, is the heart of the operation. Proper firing of the kiln will determine the quality of the final product. Cement kilns range in size from 60 feet in length and 6 feet in diameter to 760 feet in length and 25 feet in diameter. The kiln is placed in a near-horizontal position with a slope of 0.03 to 0.06 cm/m of length and rotates on its longitudinal axis. The blended feed material (wet "slurry" or dry "raw meal") is fed into the upper (highest) end of the kiln. Firing is done from the lower end of the kiln using coal, oil or gas fuel so that the exhaust gases flow countercurrent to the feed material. As the feed flows slowly down the kiln, it is exposed to higher temperatures which first cause heating, then drying, calcining, and sintering. Finally, the feed is heated to the point of fusion, resulting in clinker. Clinker, a round, marble-sized particle, is formed at approximately 1595°C. This requires process temperatures of up to 1650° at the lower end of

the kiln. The clinker is cooled in a clinker cooler and stored for finish grinding and packaging.

Older kilns use suspended chains in the drying zone to assist in moving the feed material down the kiln and to increase heat absorption from the exhaust gases. Many new dry process kilns use pre-heaters which increase energy efficiency and permit shorter kilns since heating, drying, and even calcining of the feed material can be accomplished prior to entering the kiln. Two types of preheaters are presently in use: grate and suspension preheaters. The grate preheater uses a slow moving grate which kiln exhaust gases pass through to dry and heat pelletized feed. The pellets are formed by mixing the raw feed material with 10 to 12 percent water and forming pellets approximately 2.5 cm in diameter. The hot pellets are then fed directly to the kiln.

The suspension preheater uses a multistage cyclone/suspension system to ensure direct contact of the kiln exhaust and the dry raw meal feed. The kiln exhaust gases flow counter-current to the raw meal feed through a series of staged cyclones. This system is used on dry process units only. (A state-of-the-art discussion of the reinforced suspension preheater (RSP) process can be found in Kohanowski and Shy, 1978.)

The final step of cement production is the finish grinding and packaging. Clinker is finely ground (approximately -325 mesh) in a ball mill or tube mill in one or two stages. Ground with the clinker

is a small amount of gypsum (4 to 6 percent) which controls the setting time of the cement. The portland cement is then stored, bagged, or shipped in bulk by truck, rail, barge, or ship.

4.3 Particulate Matter Characterization

Dust is generated throughout a cement plant with the largest quantities coming from the kiln and clinker cooler. Table 4-3 is a summary of the major sources of particulate matter emissions at a cement plant. The dust from burning is a mixture of substances that are nearly identical to the kiln feed with two exceptions: (1) some of the dust has been partially calcined, and (2) the dust has a high alkaline content. Partial calcination prevents recycling the dust to the feed end of a wet process kiln, since it will harden on contact with water. This problem does not occur in dry process kilns. Insufflation, adding the dust at the burner, is also used to recycle the dust if the alkalinity is not excessive. Insufflation can be used in either wet or dry process kilns.

Most kiln dust is too alkaline for recycling, however, and must be either leached with water prior to recycling (generally wet process) or disposed of, usually into settling ponds or landfills. These disposal practices lead to fugitive air emissions during transport and water pollution from leachate.

The reasons that make waste kiln dust unacceptable for recycling in the kiln also make it a potential resource (although this potential is inhibited due to the heavy metal content). The characteristics of kiln dust that make it potentially useful as a resource are

TABLE 4-3

SUMMARY OF MAJOR SOURCES
OF CEMENT DUST EMISSIONS

Process	Emission Dust Concentration (g/m^3)	Mean Size (μm)	Specific Gravity (g/cm^3)	Control
Burning (kiln)	100 - 400 (83.5 g/kg of cement)	20[a] (7 - 40)	2.3 - 2.9	ESP (wet) Fabric Filter (dry)
Clinker Cooler	50	50	--	ESP or baghouse preceded by cyclone
Finish Grinding (mill)	25 - 1000	30 (15 - 40)	2.7 - 3.1	Fabric filter preceded by separator
Bagging	10 - 40	30	--	Bag filters

[a]After control by ESP, the mean size emitted to the atmosphere is about 1 μm.

Source: Davis and Hooks, 1975.

its potassium and lime content, acid-neutralizing capacity, and ability to harden upon hydration. The dust can be used as a fertilizer or soil conditioning agent. It can neutralize acid soils and sweeten acidic lakes, bogs, or acid mine drainage. There are numerous other potential uses for kiln dust ranging from use as a water treatment flocculating agent to a source of potash.

The composition of kiln dust varies as widely as the feed material and the firing process used. Depending on chemical compound volatilities and vapor pressures, varying quantities of these compounds will end up in the kiln dust rather than in the clinker. A typical elemental composition of dried kiln dust is shown in Table 4-4. As expected, carbonate from uncalcined limestone, potassium, sodium, and calcium are the major components of kiln dust.

Under the oxidizing conditions in the high temperature clinker forming zone of the rotary kiln numerous oxides will form. Due to their high vapor pressure, some of these will volatilize and travel to the cooler portions of the kiln with the kiln exhaust. Upon cooling, these oxides will condense as a fume. The very small fume particles will exit with the kiln exhaust and be captured in the baghouse or electrostatic precipitator. Because of their very small size, the alkaline salts which form a fume will be precipitated in the last chambers of a precipitator, but will be dispersed throughout a baghouse. Table 4-5 shows an analysis of the distribution of alkalies from a kiln dust electrostatic precipitator based on particle

TABLE 4-4

TYPICAL COMPOSITION OF
DRIED KILN DUST

Component		Weight %
Clay (HCl insoluble, fired at 800°C)		4.61
Organic substance		2.06
Cations		
Lithium	Li^+	0.0064
Sodium	Na^+	12.25
Potassium	K^+	24.50
Rubidium	Rb^+	0.475
Cesium	Cs^+	0.0074
Magnesium	Mg^{++}	Trace
Calcium	Ca^{++}	9.26
Strontium	Sr^{++}	0.015
Anions		
Fluoride	F^-	0.46
Chloride	Cl^-	1.43
Bromide	Br^-	0.040
Iodide	I^-	0.0552
Carbonate	CO_3^{--}	29.59
Sulfate	SO_4^{--}	9.06
Sulfide	S^{--}	Trace
Borate	BO_3^{---}	0.152
Phosphate	PO_4^{---}	Not detectable

Heavy Metals (Weight %)			Heavy Metal Oxides (Weight %)	
Chromium	Cr	0.011	Cr_2O_3	0.016
Manganese	Mn	0.013	MnO_2	0.021
Iron	Fe	0.84	Fe_2O_3	1.19
Zinc	Zn	1.62	ZnO	2.02
Lead	Pb	0.562	PbO	0.607
Sum of all determinations				97.825
Oxygen (from CaO not bound in carbonate)				2.98
Sum of all constituents				100.805

Source: Davis and Hooks, 1975.

TABLE 4-5

PARTICLE SIZE DISTRIBUTION
OF ALKALIES IN KILN DUST

Particle Size Range (um)	Weight (Percent)	Total Alkalies (Percent)		Water Soluble Alkalies (percent)	
		Na_2O	K_2O	Na_2O	K_2O
>68	0	--	--	--	--
<68>48	0.3	0.30	3.62	a	a
<48>34	0.4	0.31	3.46	a	a
<34>24	0.7	0.35	4.51	0.094	1.927
<24>17	1.8	0.38	5.08	0.117	2.560
<17>12	5.1	0.40	5.15	0.134	3.072
<12>6	27.3	0.33	5.35	0.134	3.252
<6	64.4	0.42	10.72	0.242	8.191

[a]Insufficient sample for analysis.

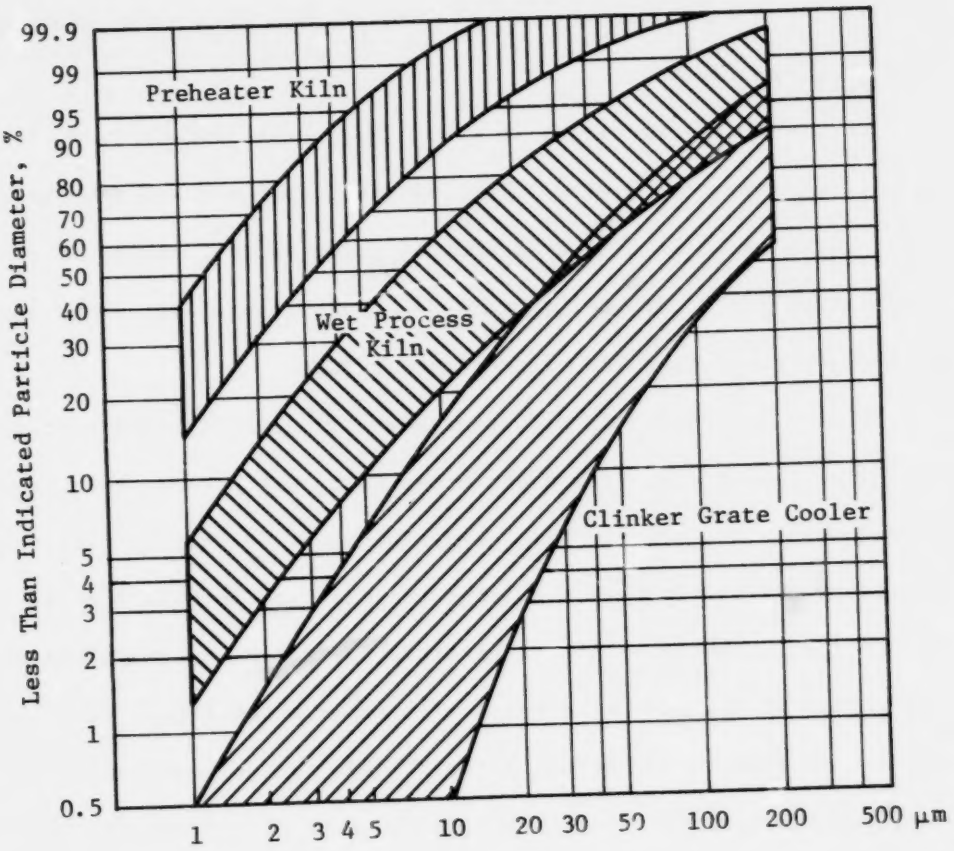
Source: Davis and Hooks, 1975

size. Over half (64.4 percent) of the alkali particles are less than 6 microns in diameter. As shown in Table 4-4, the alkalies (potassium, sodium, rubidium, etc.) form most of the kiln dust. From these analyses, one would expect the majority of kiln dust to be made up of very small particles.

Over half the particles in cement kiln dust are, in fact, less than 10 microns in diameter. This varies by process and feed material, but a particle size distribution curve showing ranges of particle sizes can be drawn (Figure 4-3). This figure also shows the particle distribution for clinker cooler dust.

Figure 4-3 shows the differences in the particle size distribution of cement dust from a preheater kiln, wet process kiln, and clinker grate cooler. In this presentation it is obvious that the particles are smallest from a preheater kiln and largest from a clinker grate cooler. This is probably due to the multicyclone configuration of the preheater which will capture the larger particles and return them to the kiln. Although data are not available, one would expect that the dust from the preheater kiln would be very high in alkaline salts, especially with 15 to 40 percent of the particles less than 1 micron in diameter.

Another characteristic of the kiln dust that is of importance to the control of emissions is resistivity. The resistivity of the dust is a factor indicating the ease of applying a negative charge to a



Source: Lind, 1978.

FIGURE 4-3
PARTICLE SIZE DISTRIBUTION OF CEMENT DUST

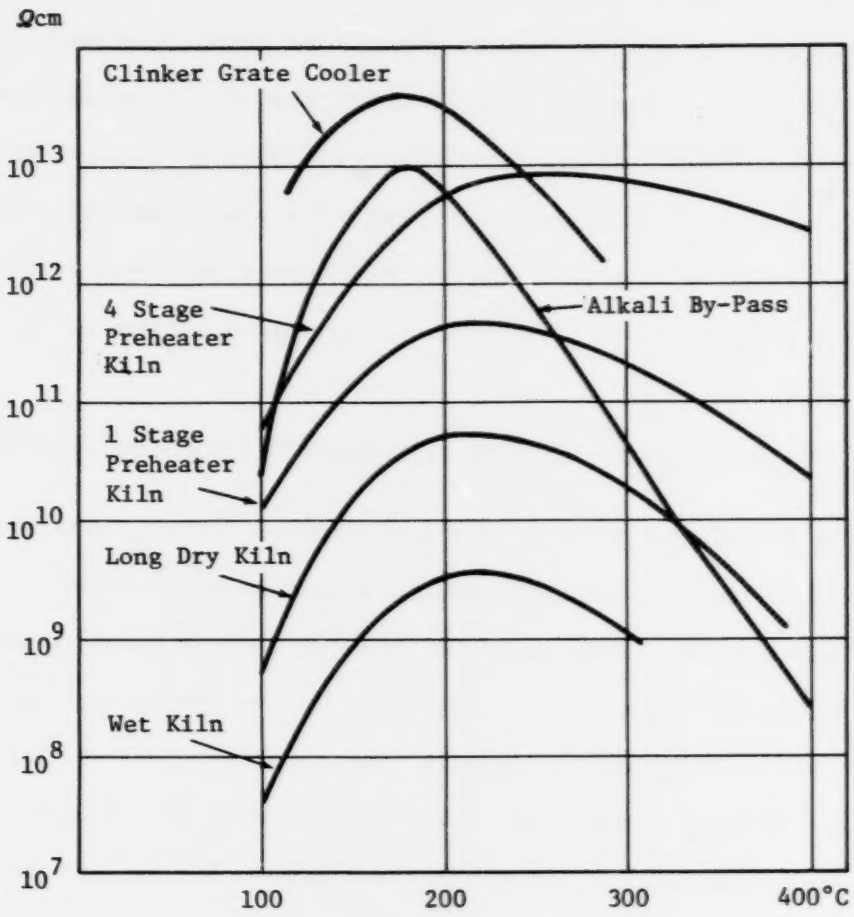
particle and determines the effectiveness of an electrostatic precipitator. From the dust resistivity data shown in Figure 4-4, it is apparent why ESPs are not used to control the particulate emissions from clinker grate coolers. On the other hand, the emissions from a wet process rotary kiln are particularly suitable for control by an ESP due to their low resistivity. Figure 4-4 also shows the effect of temperature on dust resistivity. Resistivity increases with temperature up to 200° to 250°C, above which it decreases as the temperature continues to rise.

4.4 Control Technology Applicable to the NSPS for Portland Cement Plants

Particulate matter emissions from portland cement plants are generally controlled with dry mechanical collectors of three types: cyclones, ESPs and fabric filters. However, in some cases, gravel bed filters and wet scrubbers are used. In most instances, the cyclones are used in conjunction with either a precipitator or fabric filter. Although the NSPS was based on the use of a fabric filter baghouse, other control technologies are capable of reducing emissions to meet the NSPS. These control technologies will be discussed individually in the following sections.

4.4.1 Cyclones

Cyclones are the most basic and elementary of the three types of particulate matter collectors. They are the least expensive, easiest to maintain, and have the lowest pressure drop, but are the least efficient. If an emission source is to meet the stringent air



Source: Lind, 1978.

FIGURE 4-4
RESISTIVITY OF DUST FROM PORTLAND CEMENT KILNS AND COOLERS

pollution standards, a cyclone must be followed by either an ESP or a fabric filter. Collection efficiencies of a cyclone are 60 to 80 percent depending on the particle size. The efficiency begins to drop off when the particles reach the range of 20 to 40 microns in diameter (Research Triangle Institute, 1970). Since over half the cement dust is less than 10 microns in diameter, the cyclone cannot reduce emissions sufficiently to meet the NSPS. Used in conjunction with an ESP or fabric filter, however, removal efficiencies greater than 99 percent are achievable while reducing the abrasion caused by larger particles.

4.4.2 Electrostatic Precipitators

Electrostatic precipitators operate by maintaining a corona discharge between a negatively charged electrode and a grounding plate. The exhaust gas stream passes through the corona discharge, and entrained particles pick up a charge. The charged particles are attracted to the grounding plates where they agglomerate. The cleaned gas stream continues on to the stack, while the agglomerated particles are removed from the plates by frequent "rapping" and fall into dust hoppers for future removal and disposal.

A number of variables influence the efficiency of an ESP: gas velocity, moisture content and temperature, and dust quantity, particle size, resistivity and physical characteristics. Although all of these variables are important to the designer, dust particle resistivity is the most important. Particles with a high resistivity will

not acquire a charge when they pass through the corona discharge. Kiln dust from a preheater kiln has a resistivity which makes an ESP unsuitable. The resistivity can be reduced, however, by treating the exhaust gas prior to its entry into the ESP. Moisture control is the easiest method of pretreatment. As the moisture content of the dust is raised, the resistivity is reduced. This is a primary reason for the reduced resistivity of dust from a wet process kiln.

Chemical exhaust gas conditioning is growing in use. Polar compounds adsorbed on the surface of particles can reduce resistivity and increase the ESP collection efficiency. This has been demonstrated as a viable method of reducing particulate emissions from power plants converting to coal fuel. Chemical conditioning has the advantages of rapid installation (4 to 6 weeks) and cost (capital: 10 to 25 cents/kW capacity, and operation: 0.2 mil/kWh) (Chemical & Engineering News, 1978).

The advantages of an ESP are:

1. The ability to handle large volumes of gas with very little pressure drop.
2. Relatively lower power requirements (compared to fabric filters) due to the low pressure drop.
3. The ability to handle high temperature gases and corrosives.

These advantages must be weighed against the disadvantages of using an electrostatic precipitator at a cement plant:

1. The entire ESP must be shut down and bypassed for maintenance or repairs when required.

2. Sulfur oxides in the exhaust gas corrode the metal parts causing reduced efficiency.

3. Sulfur acids can diffuse into concrete casings and eventually destroy them.

4. Alkalies can coat high-voltage components and cause short circuits.

Also, an ESP must be bypassed during startup due to a fire and explosion hazard from unburned fuel in a chamber with electrical arcing.

4.4.3 Fabric Filters

Fabric filters are one of the oldest methods of removing dust from a gas stream. The cement industry uses glass fiber filters because they are reliable, efficient in removing particles in the size range of concern, and capable of withstanding high temperatures. Fabric filters are capable of greater than 99.5 percent removal of cement dust from cement plant exhaust streams.

The advantages of fabric filters are:

1. Reliability

2. Lower cost due to simplicity

3. Very high removal efficiencies

4. Rapid repairs and the opportunity to isolate areas for repair and maintenance without bypassing the entire bag-house.

Baghouses have disadvantages also:

1. Increased pressure drop (relative to ESP) which must be overcome by induced draft.

2. Increased cost of draft equipment may overcome the other cost advantages.

3. Susceptibility to clogging from moisture.

4. Bag-life is very dependent on temperatures and is limited to less than 315°C (600°F).

In general, it appears that the glass-fabric baghouse would be used for collecting particulate matter from the dry-process kiln and clinker cooler gases and electrostatic precipitators would be the choice for wet-process kilns. However, it has been reported that a higher collection efficiency can be maintained with the baghouse than the precipitators (Research Triangle Institute, 1970) and, in fact, the baghouse is used on both wet and dry process kilns.

A survey of NSPS affected facilities shows 12 kilns with precipitators and 16 with baghouses. Eighteen out of 22 clinker coolers at these NSPS sites use baghouses to control particulate emissions. Additional details on this data are discussed in Section 4.5.

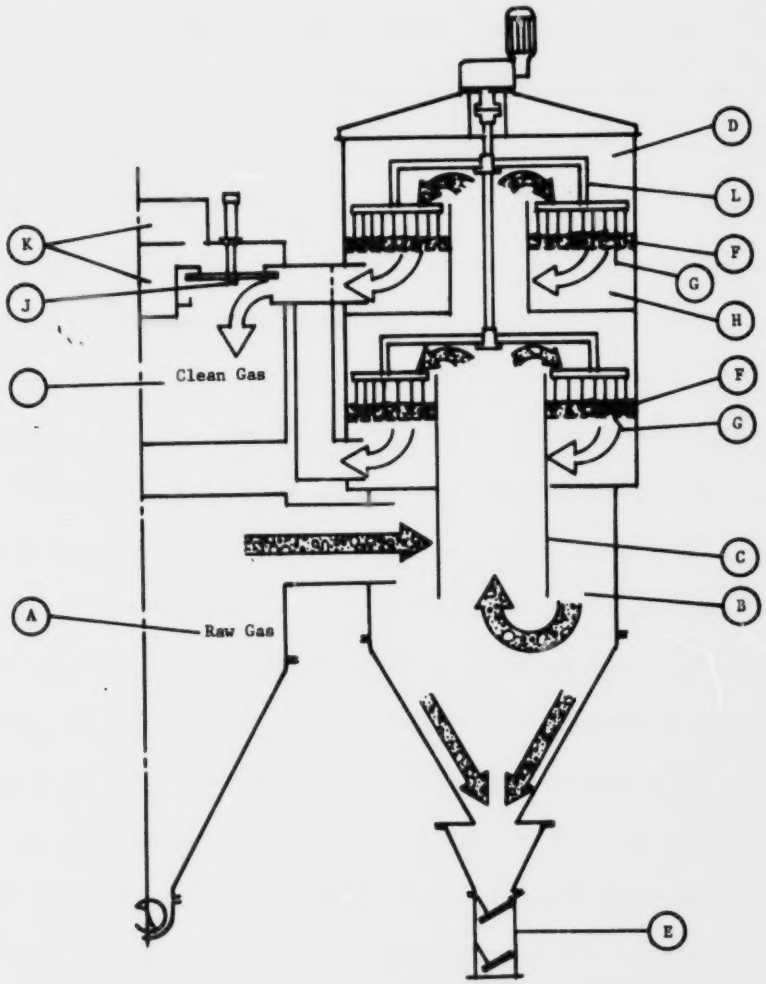
4.4.4 Gravel Bed Filters

Gravel bed filters have been in use since 1957, primarily in Europe. Recently they have been used for particulate matter control in the domestic cement industry. In the period 1972-1978, Rexnord, Inc., installed 24 gravel bed filters on domestic clinker coolers. The available data show only two of these on sources subject to NSPS--National Cement Company, Ragland, Alabama; and U.S. Steel, Leeds, Alabama. The compliance test results show both these units as in compliance with 74 percent and 91 percent of allowable emissions, respectively.

Figure 4-5 shows a cutaway drawing of a Rexnord, Inc. gravel bed filter. The particle-laden gases from a clinker cooler or kiln preheater enter the module at the raw gas inlet (A) and enter the cyclone. The cyclone (B) removes the larger particles and the gas stream moves up the vortex tube (C) and into the raw gas chamber (D), while the large dust particles are removed through a double tipping gate (E) at the bottom of the cyclone. The raw gas is directed through the filter medium (F) where the remaining dust is removed. The gas stream passes through the media support screen (G), into the clean gas chamber (H), and out of the module through the clean gas outlet duct (I). When the filter media becomes clogged, the module is backflushed by opening the backflush control valve (J) and forcing clean air through the backflush duct (K). This air passes up through the filter medium (F), while stirring rakers (L) agitate the medium. The dust, which had been trapped in the filter medium, is removed and directed back down the vortex tube (C) and either out the double tipping gate or out the raw gas intake and to another module's cyclone. Only one module is backflushed at a time so that particulate matter control is in operation at all times.

Advantages of the gravel bed filter, as reported by Shumway et al. (1978), include:

1. Rapid construction (approximately 4 months)
2. Low maintenance costs (average $2,000/year)
3. Handling of increased gas flow during upset conditions



(A) Raw Gas Dust

(B) Primary Collector (Cyclone)

(C) Vortex Tube

(D) Raw Gas Chamber

(E) Double Tipping Gate (Dust Discharge)

(F) Gravel Bed Filter Medium

(G) Screen Support for Bed

(H) Clean Gas Chamber

(I) Exhaust Port

(J) Backflush Control Valve

(K) Backflush Duct

(L) Stirring Raker

Source: Shumway et al., 1978.

FIGURE 4-5
REXNORD, INC. GRAVEL BED FILTER

4. Continuous particulate matter control during periods of maintenance or repair

5. Handling of high temperature gases (>371°C (>700°F) at Missouri Portland, Joppa, Illinois).

4.4.5 Wet Scrubbers

Wet scrubbers are not used very much in the portland cement industry. Only one unit is in operation on a NSPS-affected facility (clinker cooler). The principle of operation of a wet scrubber is simply to trap a small dust particle in or on a larger water droplet and then remove the droplet in a cyclone.

Wet scrubbers are used in areas where elevated gas temperatures, or sticky or hygroscopic dust is encountered. They are also suitable in areas where there is a preference for collected dust in a slurry form. They are not suitable for dust particles of submicron diameter, dust which becomes corrosive when wet, or when there is a preference for collected dust in a dry form.

These attributes and shortcomings make wet scrubbers suitable for particulate matter control on clay dryers and in primary crushing, screening and secondary rock crushing. In each of these situations, there may be sufficient moisture in the gas stream to cause condensation problems in dry collectors.

4.5 Comparison of Levels Achievable with Best Demonstrated Control Technology Under the Present NSPS

The available data on control technologies for the removal of particulate matter from exhuast gas streams at portland cement plants show that a number of controls are suitable for reducing emissions

below the level required by the NSPS. The technologies are described in Section 4.4. Table 4-6 summarizes the ranges of emissions from control systems in use on NSPS-affected facilities. Since the NSPS for portland cement plants do not specify a mass emission limit for sources other than kilns and clinker coolers, there are no data to show the effectiveness of controls used for fugitive emissions or emissions from grinding, drying, blending, packaging, etc., operations.

As discussed in Section 4.4, there is no single best demonstrated control technology for particulate matter emissions from portland cement plants. Rather, there are four technologies that are preferable under different circumstances within a plant and at different plants. Most portland cement plants use some combination of cyclone, ESP, baghouse, and gravel filter to reduce the emission of particulate matter.

TABLE 4-6

RANGES OF DUST EMISSION FROM CONTROL SYSTEMS SERVING NSPS PORTLAND CEMENT PLANTS

Source	Type of Dust Collector	Range of Dust Emissions From Collector (kg/Mg)[a]
Kiln - dry	ESP	0.021-0.125
	Baghouse	0.013-0.124
	Gravel Bed	NA[b]
Kiln - wet	ESP	0.020-0.142
	Baghouse	0.049-0.132
	Gravel Bed	NA
Clinker Cooler	ESP	NA
	Baghouse	0.005-0.061
	Gravel Bed	0.023-0.045
	Wet Scrubber	0.022-[c]

[a]Kilograms of particulate matter per metric ton of kiln feed.
[b]NA = No compliance test data.
[c]Single compliance test result.

Source: MITRE Corporation, 1978.

5.0 INDICATIONS FROM NSPS COMPLIANCE TEST RESULTS

5.1 Test Coverage in the EPA Regions

The Metrek Division of the MITRE Corporation conducted a survey of all 10 EPA Regional Offices to gather available NSPS compliance test data for each of the 10 industries under review (Watson et al., 1978). This survey yielded test data on 28 new portland cement kilns/clinker coolers. The data included average particulate matter emissions and opacity measurements for these units. Only a few opacity readings were reported, as compared with the total number of tests.

Information received from the Portland Cement Association indicated that numerous additional NSPS-affected facilities existed. Telephone contacts with EPA Regional personnel, State Air Pollution Control Agencies, and, in some cases, with portland cement plant operators yielded NSPS compliance test data on an additional 21 facilities. Data were not obtained for seven other possible NSPS cement kilns. According to industry reports, this information represents all of the portland cement plants completed from 1971 through 1978, and subject to the NSPS (MITRE Corporation, 1978).

5.2 Analysis of the NSPS Test Results

The results of the NSPS compliance tests for 49 portland cement NSPS-affected facilities are tabulated in Table 5-1 and displayed in Figures 5-1 (cement kilns) and 5-2 (clinker coolers). Only one cement kiln subject to the NSPS is unable to pass a NSPS compliance

TABLE 5-1

NSPS COMPLIANCE TEST RESULTS FOR PORTLAND CEMENT PLANTS

Plant	Kiln	Year Compl'd	Capacity (Mg/day)	Pre-heater	Process	Fuel	Control Technology: Kiln	Control Technology: Clinker Cooler	Compliance Test Data: Kiln: Part (kg/Mg)	Compliance Test Data: Kiln: Opacity (%)	Compliance Test Data: Clinker Cooler: Part (kg/Mg)	Compliance Test Data: Clinker Cooler: Opacity (%)	Remarks
REGION I													
None													
REGION II													
Flintkote Company Glens Falls Portland Div., Glen Falls, N.Y.	1	1973	1486	X	Dry	Oil	ESP	Bag	0.021 (0.088)	0	0.017	IC	Roller mill on, normal bypass. Initial test 1974. Retested 1975.
San Juan Cement Dorado, P.R.	3	1976	1154		Wet	Oil	Bag	Bag	0.0	IC	--	--	Average of tests taken on four days.
REGION III													
Copley, Nazareth, Pa.	1	1978	2819	X	Dry	Coal			--	IC	--	--	Test data not yet available.
Lone Star, Citadel Cement Corp., Roanoke, Va.	5	1976	1488	X	Dry	Coal	Bag		0.013	0	--	--	Cannot pass SO_2 for PSD(using high sulfur oil fuel)
Whitehall Cementon, Pa.	3	1975	619	X	Dry	Coal	Bag		0.089	0-20	--	--	
REGION IV													
Citadel Cement Corp. Demopolis, Ala.	1	1977	2132	X	Dry	Coal			--	--	--	--	Test data not yet available.
National Cement Co. Ragland, Ala.	1	1976	1996	X	Dry	Coal/ Oil	ESP	Gravel Bed	0.055	<10	0.035	<10	Flash calciner; kiln capacity increases to <30% in bypass.
Universal Atlas Cement Div. of U.S. Steel Corp. Leeds, Ala.	1	1976	1619	X	Dry	Coal	ESP	Gravel Bed	0.062	5	0.45	5	Kiln = 0.062 kg/Mg mill on; 0.057 kg/Mg bypassed at ≤50% opacity.
Florida Mining & Materials Brooksville, Fla.	1	1975	1542	X	Dry	Coal	Bag	Bag	0.033	IC	0.015	IC	
Maule Industries, Inc. Hialeah, Fla.	3	1975	1950		Wet	Gas	ESP	Bag	0.02	IC	0.035	IC	
Medusa Cement Co. Clinchfield, Ga.	2	1974	1504	X	Dry	Coal	Bag	Bag	0.104	IC	0.028	IC	
Flintkote Rosmoedale, Ky.	1	1974	1755	X	Dry	Coal	ESP	Bag	0.051	IC	0.039	IC	
Texas Industries Artesia, Miss.	1	1974	1034		Wet	Gas	ESP	Wet Scrubber	0.105	IC	0.022	IC	

TABLE 5-1 (Continued)

NSPS COMPLIANCE TEST RESULTS FOR PORTLAND CEMENT PLANTS

Plant	Kiln	Year Compl'd	Capacity (Mg/day)	Pre-heater	Process	Fuel	Control Technology: Kiln	Control Technology: Clinker Cooler	Compliance Test Data: Kiln Part (kg/Mg)	Compliance Test Data: Kiln Opacity (%)	Compliance Test Data: Clinker Cooler Part (kg/Mg)	Compliance Test Data: Clinker Cooler Opacity (%)	Remarks
Giant Portland Cement Harleyville, S.C.	4	1974	590		Wet	Gas	Bag	Bag	0.123	5	0.043	5	
Gifford-Hill Cement Harley ille S.C.	1	1974	1506	X	Dry	Gas	Bag	Bag	0.052	20	0.017	IC	
Santee Portland Cement Holly Hill, S.C.	2	1974	1961		Wet	Gas	ESP	Bag	0.129	IC	0.035	IC	
REGION V													
Missouri Portland Joppa, Ill.	2	1975	2177	X	Dry	Coal	ESP		0.050	IC	--	--	
Centex LaSalle, Ill.	1	1974	898	X	Dry	Coal			--	--	--	--	Questionable status as new source.
Louisville Cement Speed, Ind.	1	1973	1017		Dry	Coal		Gravel Bed	--	--	--	--	
	2	1977	2420		Dry	Coal			0.113-0.088	IC	0.023	IC	Two compliance tests on kiln with average of 0.1 kg/Mg.
National Gypsum Alpena, Mich.	22	1975	1488		Dry	Coal	Bag		0.070	0	--	--	Both kilns vented to common baghouse & stack. State test done on stack in kg/Mg product.
	23	1975	1488		Dry	Coal	Bag						
Southwestern Portland Cement, Fairborn, Ohio	2	1974	1665	X	Dry	Coal	Bag	Bag	0.123	0	0.007	0	
Lehigh, Mitchell, Ind.	3	1976	653	X	Dry	Coal			--	--	--	--	Out of compliance. No test data submitted.
REGION VI													
Centex, Austin Cement Co., Buda, Tex.	1	1978	1500		Dry		Bag	Bag	0.033	IC	0.012	IC	
Gifford-Hill Cement Midlothian, Tex.	3	1972	753		Wet	Coal/ Gas	ESP		0.028	IC	--	--	
Kaiser, San Antonio, Tex.	4	1975	1052	X	Dry	Coal	Bag	Bag	0.017	IC	0.005	IC	
OKC, New Orleans, La.	2	1974	880		Wet	Coal	Bag		0.049	IC	--	--	Tested in compliance, later found out of compliance & retested. Presently in compliance.

TABLE 5-1 (Concluded)

NSPS COMPLIANCE TEST RESULTS FOR PORTLAND CEMENT PLANTS

Plant	Kiln	Year Compl'd	Capacity (Mg/day)	Pre-heater	Process	Fuel	Control Technology Kiln	Control Technology Clinker Cooler	Compliance Test Data Kiln Part (kg/Mg)	Kiln Opacity (%)	Clinker Cooler Part (kg/Mg)	Clinker Cooler Opacity (%)	Remarks
REGION VII													
Ash Grove Cement Co. Louisville, Neb.	4	1975	1170	X	Dry	Coal/ Gas	ESP	Bag	0.125	5-15	0.061	5-10	
Northwestern States Mason City, Iowa	3	1976	771		Dry	Coal	Bag	Bag	0.073	IC	0.011	IC	
Monarch Cement Co. Humboldt, Kan.	5	1975	762	X	Dry	Gas	Bag	Bag	0.123	5	0.009	0	
REGION VIII													
Utah Portland Cement Co. Salt Lake City, Utah	4	1975	454		Wet	Coal/Oil/ Gas	High efficiency cyclone followed by baghouse		--	--	--	--	No file at Region
Ideal, Portland, Col.	3	1976	1270		Wet	Coal	ESP	Bag	0.077	20	0.014		
Ideal, Trident, Mont.	1	1973	834		Wet	Coal	ESP		0.142	IC	--	--	Tested at 6.3 lb/hr.
South Dakota Cement Rapid City, S.D.	4	1977	1542	X	Dry	Coal			--	--	--	--	Plant breakdown during test
REGION IX													
Monolith Portland Monolith, Cal.	1	1974	1315		Wet	Coal	Bag	Bag	0.132	10	0.007	0	Initial cooler test was 0.1 kg/Mg
REGION X													
None													

IC - In compliance.

Source: MITRE Corporation, 1978.

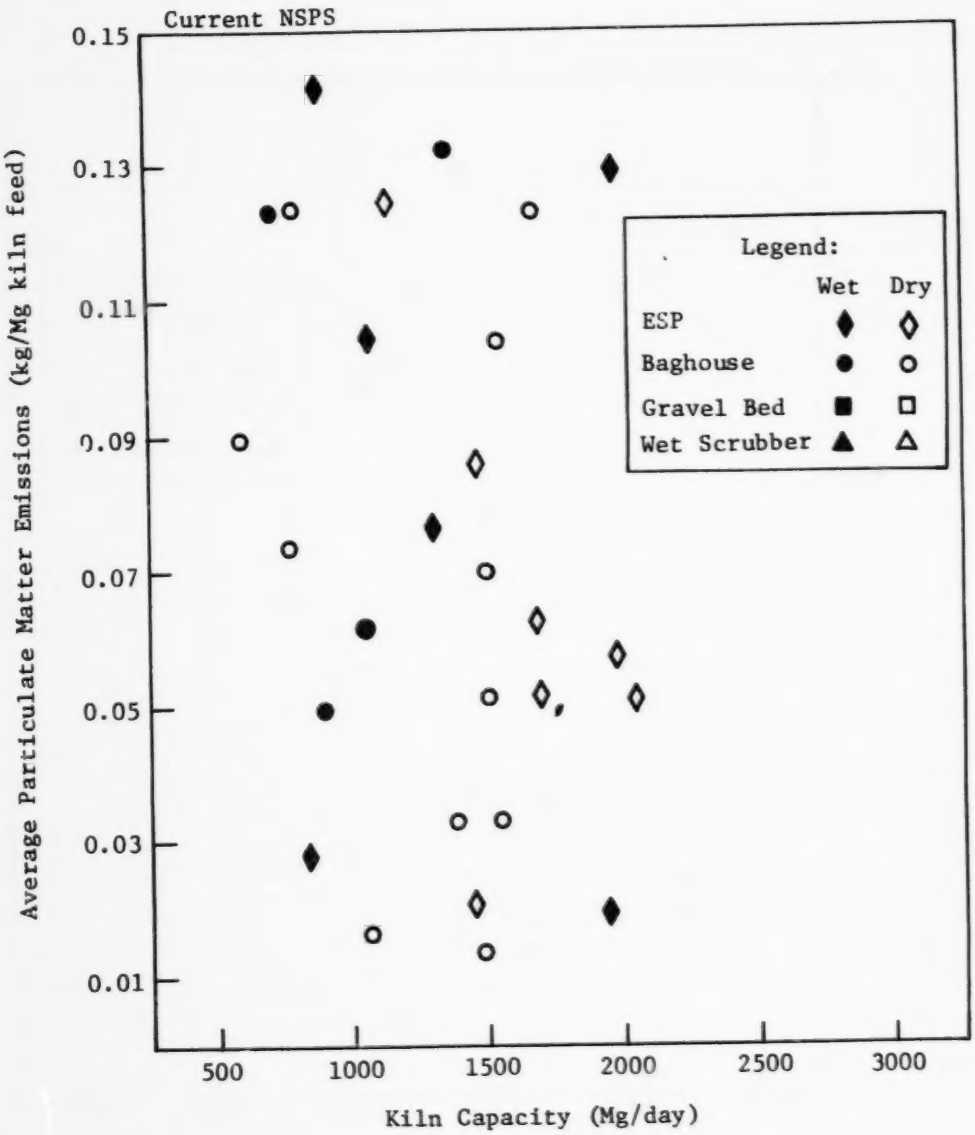


FIGURE 5-1
PORTLAND CEMENT PLANTS NSPS COMPLIANCE TEST RESULTS
KILN PARTICULATE MATTER EMISSIONS

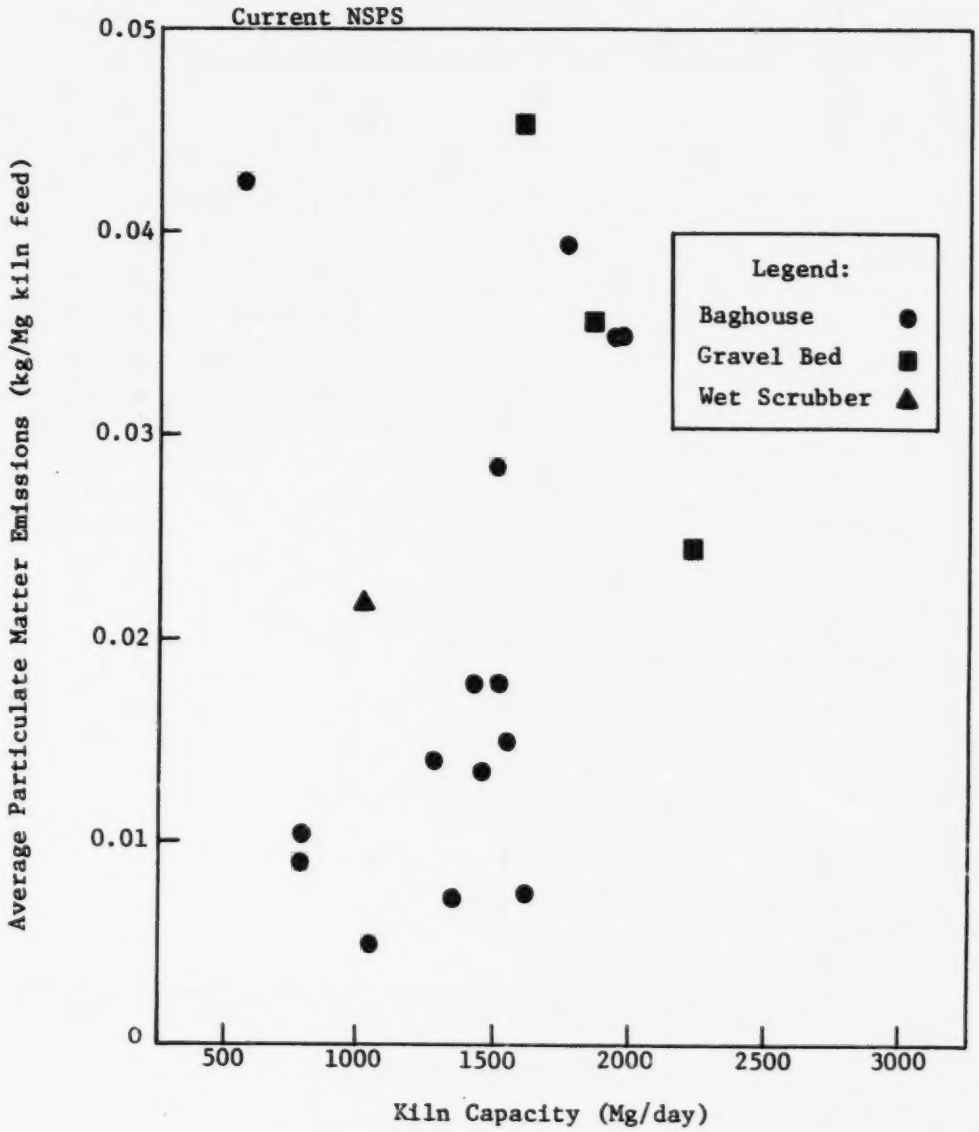


FIGURE 5-2
PORTLAND CEMENT PLANTS NSPS COMPLIANCE TEST RESULTS
CLINKER COOLER PARTICULATE MATTER EMISSIONS

test--Lehigh Cement, Mitchell, Indiana--and the company has not submitted to state air pollution officials any test data to indicate how much their emission level exceeds the NSPS limit. All clinker coolers and other affected facilities are reported to be in compliance.

5.2.1 Control Technology Used to Achieve Compliance

Data received show that all 29 cement kilns and 20 clinker coolers are in compliance with the NSPS. Of the remaining 7 NSPS-affected cement kilns, five are known to be in compliance, one is known to be out of compliance, and one has just recently been tested and the results have not yet been analyzed.

The particulate matter emissions from the portland cement plants are controlled by ESPs, fabric filter baghouses, gravel bed filters, and wet scrubbers. Table 5-2 summarizes results of using these different control technologies on cement plant exhaust streams.

Cement kilns have been tested at emission levels ranging from a high of 0.142 kg/Mg feed and a low of 0.013 kg/Mg feed. The range for kilns with emissions controlled by ESP is 0.142 to 0.020 kg/Mg, and for kilns with fabric filter baghouses the range is 0.132 to 0.013 kg/Mg dry kiln feed. The data indicate that neither the ESP nor the baghouse is significantly better at controlling cement kiln particulate matter emissions.

Cement plant clinker coolers have been tested at emission levels ranging from a high of 0.061 kg/Mg and a low of 0.005 kg/Mg dry kiln

TABLE 5-2

RESULTS OF USING VARIOUS PARTICULATE MATTER CONTROL TECHNOLOGIES AT PORTLAND CEMENT PLANTS

Affected Facility	Electrostatic Precipitator	Fabric Filter Baghouse	Gravel Bed Filter	Wet Scrubber
Kiln Emissions (kg/Mg feed)				
#Units	12[a]	16[a]	0	0
Maximum	0.142	0.132	--	--
Minimum	0.020	0.013	--	--
Clinker Cooler Emissions (kg/Mg feed)				
#Units	0	16[a]	3[a]	1[a]
Maximum	--	0.043[b]	0.045	0.022
Minimum	--	0.005	0.023	0.022

[a]Number of units with available test data.
[b]A single compliance test shows 0.061 kg/Mg. The EPA Region states that the source is in compliance

Source: MITRE Corporation, 1978.

feed (mean 0.024 kg/Mg). Compliance test data on a single wet scrubber show emissions near the mean emission level for fabric filter baghouse controls (0.022 kg/Mg). Data for affected facilities using gravel bed filters indicate a mean emission level of 0.034 kg/Mg dry feed (0.023-0.045 kg/Mg).

5.2.2 Analysis of Compliance Test Data

The compliance test data shown in Table 5-1 were analyzed to determine if any of the following variables affected the ability to control the emission of particulate matter from portland cement kilns or clinker coolers:

- Kiln control technology - ESP or baghouse
- Kiln control technology as a function of production process - wet or dry
- Kiln production process - wet or dry
- Clinker cooler control technology - baghouse, gravel bed filter, or wet scrubber.

The results of this analysis are summarized in Table 5-3. The compliance test data were grouped into sets corresponding to the previously mentioned variables, which facilitate comparisons of the effectiveness of any single control technology, if a control was more effective on a particular process, or if the effect of available controls was more pronounced on a specific process. The table shows the number of compliance tests, the range and the mean of the test results, and the standard deviation and standard error of each set of data.

TABLE 5-3

ANALYSIS OF PORTLAND CEMENT PLANT COMPLIANCE TEST DATA

Variable	Statistic						
	Number Values[a]	Minimum[b]	Maximum[b]	Mean	Standard Error	Standard Deviation	NSPS
Dry Process							
ESP	8	0.021	0.125	0.061	0.012	0.033	0.15
Baghouse	10	0.013	0.123	0.070	0.013	0.041	
Wet Process							
ESP	6	0.020	0.142	0.084	0.021	0.051	
Baghouse	4	0.049	0.132	0.091	0.021	0.043	
All Processes							
ESP	14	0.020	0.142	0.070	0.011	0.041	
Baghouse	14	0.013	0.132	0.076	0.011	0.041	
All Controls							
Dry Process	18	0.013	0.125	0.066	0.009	0.037	
Wet Process	10	0.020	0.142	0.087	0.014	0.046	
All Kiln Data	28	0.013	0.142	0.073	0.008	0.040	
Clinker Cooler							
Baghouse	16	0.005	0.061[c]	0.022	0.004	0.016	0.05
Gravel Bed	3	0.023	0.045	0.034	0.006	0.011	
Wet Scrubber	1	0.022	0.022	-	-	-	
All Controls	20	0.005	0.061	0.024	0.003	0.015	

[a]Number of compliance tests.

[b]Particulate emissions in kg/Mg feed.

[c]A single compliance test shows 0.061 kg/Mg. The EPA Region states that the source is in compliance.

Source: MITRE Corporation, 1978.

A comparison of the mean values for each set of compliance test data indicates that no control technology in use today is more effective for controlling particulate matter emissions. The mean values also indicate that there is a possibility that emissions from dry process kilns are controlled slightly more effectively than wet process kilns. Further analysis shows that this is not, in fact, a statistically significant difference. The standard deviation, a measure of the variability of the test results, indicates that the current NSPS is set at a level that ensures continuous compliance with an adequate margin of safety.

5.3 Indications of the Need for a Revised Standard

5.3.1 Particulate Matter Standard for Portland Cement Kilns

There is not sufficient justification for revision of the present standard for cement kilns based on the following considerations:

- The current best demonstrated control technology is either fabric filter or ESP. However, the original background study used fabric filter technology as the basis for the standard. This technology has not changed during the past 8 years. Although the ESP has improved, test results ate that it is not capable of significantly better performance than fabric filters.

- Although the mean emission rate for the 28 compliance tests analyzed was 0.073 kg/Mg dry kiln feed, the range was from 0.142 to 0.013 kg/Mg dry kiln feed with 16 kilns tested above and 13 below the mean. There was a random spread of test results throughout the range of values, indicating that there is no control or process technology that is consistently better at reducing emissions or having emissions reduced.

- Although no data are available, it is generally accepted knowledge that control technologies being used at cement plants deteriorate with age. Baghouses, ESPs, and cyclones

are all subject to erosion, clogging, tearing, shorting, or similar problems with time. As the controls deteriorate, the level of emissions is expected to increase.

5.3.2 Particulate Matter Standard for Portland Cement Clinker Coolers

There is not sufficient justification for revision of the present standard for clinker coolers based on the following considerations:

- Fabric filters remain the primary control technology for removing particulate matter from clinker cooler exhaust gases and are identical to those used as the rationale for setting the standard in 1971.
- The same problems with deterioration apply to both clinker cooler and kiln emission control.
- An analysis of the compliance test data indicates that the current NSPS is set at a level that ensures continuous compliance with an adequate margin of safety.

5.3.3 Opacity Standards

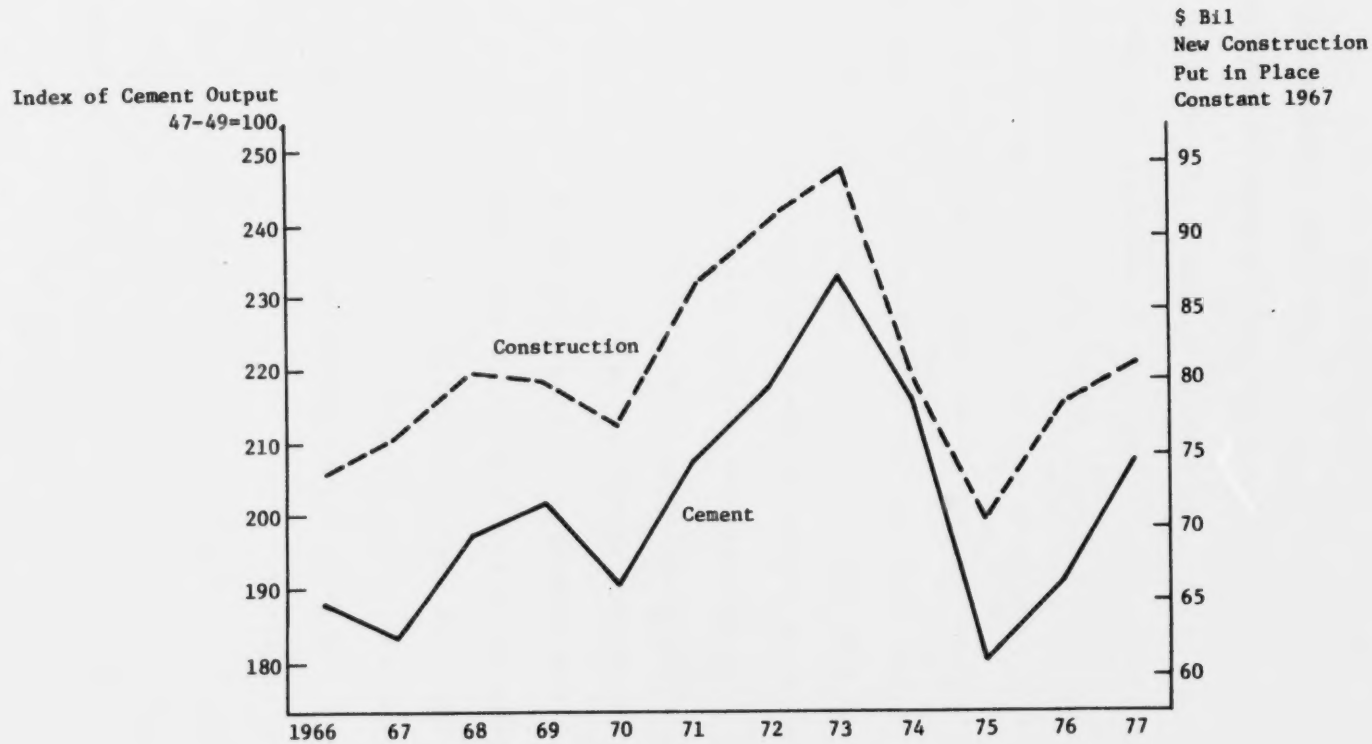
The opacity standard has been studied thoroughly in answer to a Court remand in 1973. No changes have occurred in the industry to invalidate the conclusions of that study.

6.0 ANALYSIS OF THE IMPACTS OF OTHER ISSUES ON NSPS

6.1 Industry Economics and New Construction

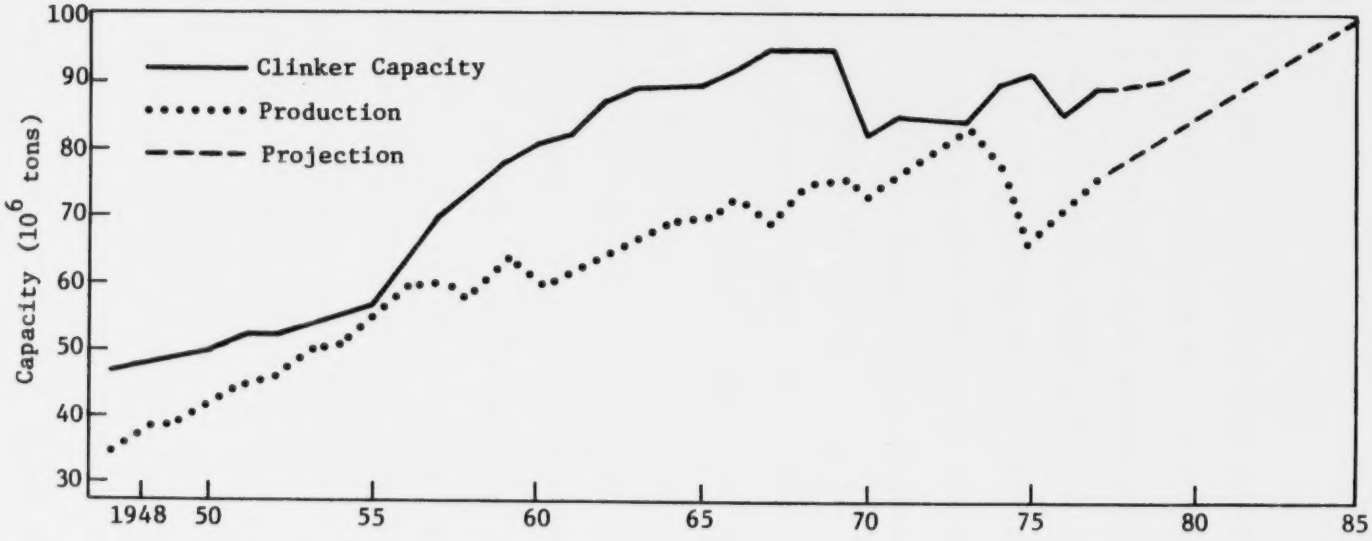
The historical growth pattern of the cement industry shows its close ties with the construction industry. Figure 6-1 displays how the production of cement has paralleled construction spending in the U.S. for the period 1966-1977. It is estimated that cement is a necessary input to 90 percent of all construction projects and 99 percent of all cement is used in construction (Bureau of Mines, 1976). The clinker capacity of the industry however has not followed this pattern very closely. Figure 6-2 shows the comparison of clinker capacity and production for the period 1945 through 1977. Future capacity and production growth estimates are also shown. From this graph, it is obvious that although cement production and construction are closely related, clinker capacity and construction are not. A number of external events can be noted which preceded the wide fluctuations between clinker capacity and production. These include a post war housing boom in the late 1940s and early 1950s, another construction boom in the early 1970s, the Clean Air Act of 1970, New Source Performance Standards in 1971, price and wage controls in 1971, the Clean Air Act Amendments of 1972 and an economic recession in 1973-1975.

The cement industry built no "greenfield" plants (plants constructed at a new site location) during the period 1931 to 1945 (Mongoven, 1977). During the post-World War II era, the immediate



Source: Mongoven, 1977.

FIGURE 6-1
CONSTRUCTION SPENDING AND CEMENT OUTPUT



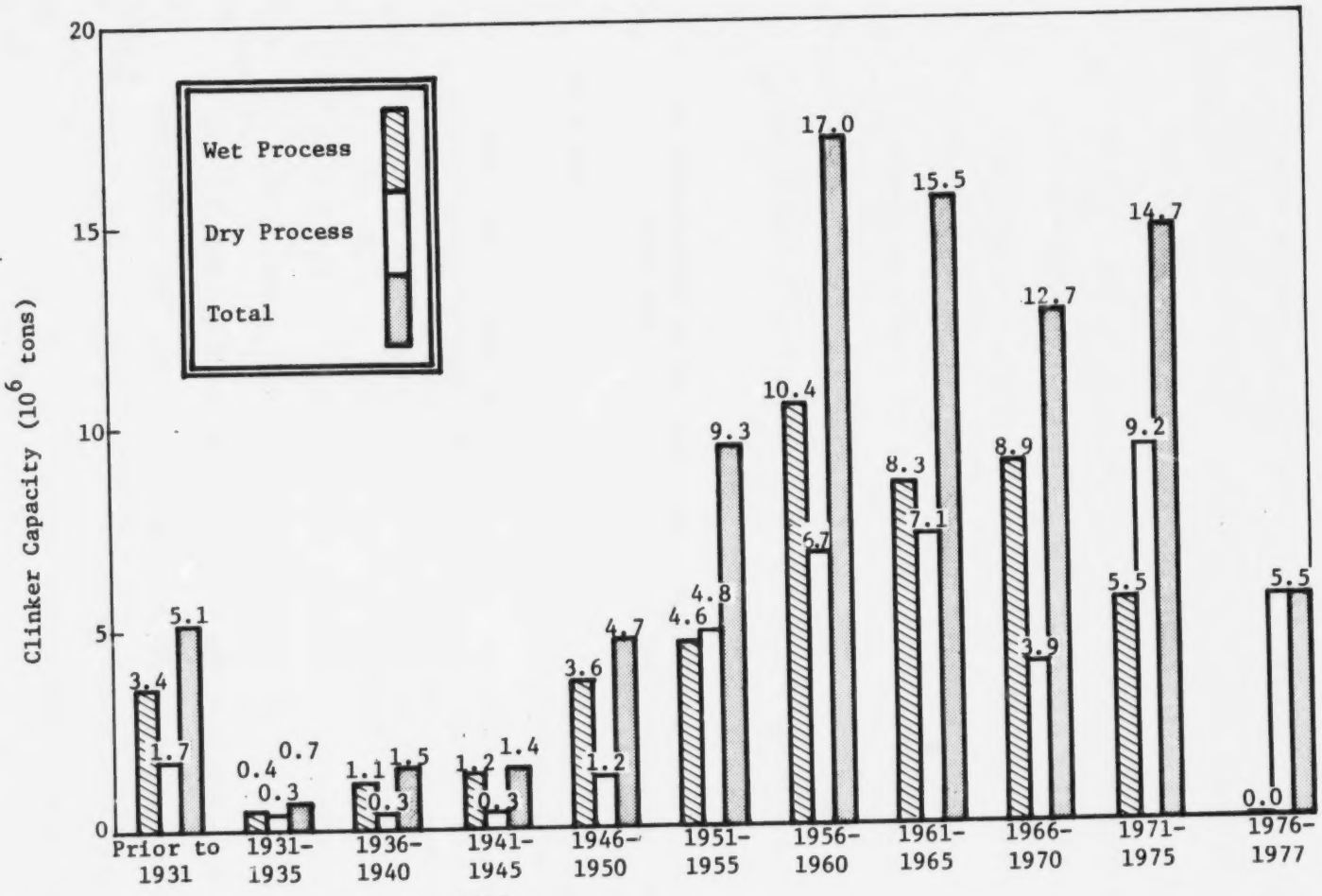
Source: Bureau of Mines, 1978.

FIGURE 6-2
U.S. PORTLAND CEMENT CAPACITY AND PRODUCTION

demand for cement by the construction industry was met by capacity released from war production. In 1947 the industry utilization of capacity was 75 percent (Bureau of Mines, 1973). This steadily increased to greater than 90 percent utilization during 1953-1956 with the post-war housing boom and peaked in 1955 at 94.3 percent (Bureau of Mines, 1973). Due to the regional nature of the industry, regional shortages were encountered while the industry was realizing greater than 15 percent return on sales (Mongoven, 1977).

During the period 1955-1967, cement production capacity increased 61.4 percent, approximately two-thirds of the total post war increase occurring in this 12-year period (Bureau of Mines, 1973). Figure 6-3 shows that although a relatively large number of kilns built prior to 1946 (20 percent) are still operating, these kilns account for only 10 percent of clinker capacity. In the early 1960s, the industry was faced with overcapacity. The utilization of production capacity dropped to less than 80 percent (Bureau of Mines, 1973). Where production had increased 50 percent during the 1950s, production increased only 15 percent during the 1960s (Bureau of Mines, 1973).

In the late 1960s and early 1970s, utilization of production capacity slowly climbed once again to greater than 90 percent in 1972-1973 (Bureau of Mines, 1973). At the time, little new capacity was built, while older plants were closed due to age and the new pollution control standards. Several existing cement plants closed because industry did not feel that the additional capital cost for



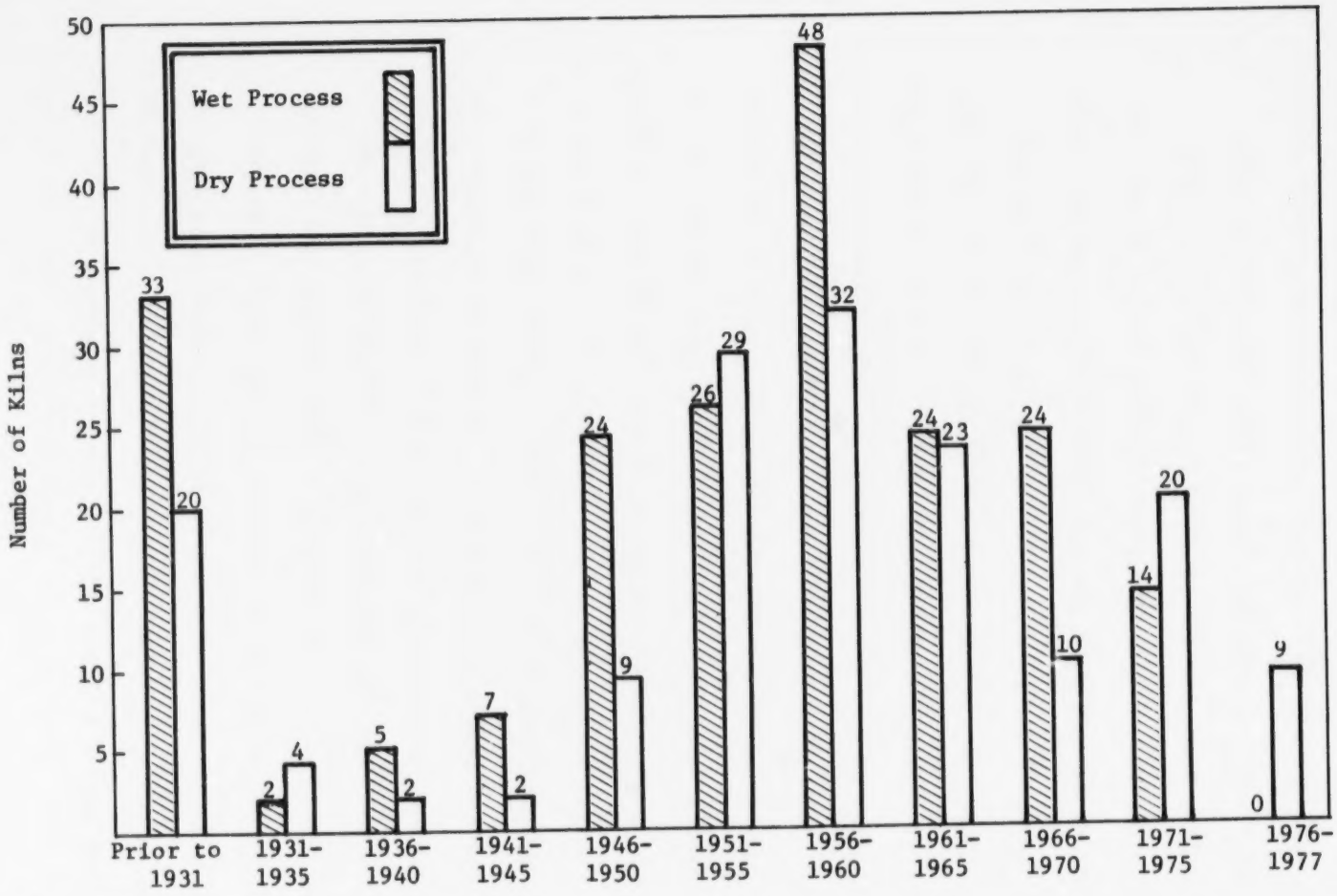
Source: Portland Cement Assn, 1978.

FIGURE 6-3
CEMENT PLANT CLINKER CAPACITY
BY AGE OF KILN

pollution control equipment could be justified at obsolete plants. According to Daugherty and Wist (1974) 15 plants had closed due chiefly to environmental pressures. Figure 6-4 shows the age and number of kilns presently operating in the U.S. A total of 14 percent of these kilns were built prior to 1931 and over 20 percent prior to 1946. Rarely are these older facilities closed solely because of pollution abatement requirements. The Bureau of Economic Analysis (Department of Commerce) surveyed 131 industrial closings over the period 1974-1977 that involved pollution abatement requirements. The hypotheses that they suggested from their survey results were that:

- First, most permanent closings involving pollution problems did not occur solely because of pollution abatement requirements.
- Second, the number of permanent closings fell after 1975 when general economic conditions improved.
- Third, air pollution requirements contributed to more permanent closings than water pollution requirements, possibly because of a combination of the Clean Air Act of 1970 deadline of 1975 and the slack economic conditions in 1974 and early 1975 (Rutledge et al., 1978).

The closings may have been a contributing factor in the regional lack of capacity in 1972-1973. It is more likely, however, that this shortage was a result of the price and wage controls imposed in 1971 which held the price of portland cement at a level that ensured the industry its lowest profit margin since the Depression in the 1930s (Frondistun-Yannas, 1976).



Source: Portland Cement Assn, 1978.

FIGURE 6-4
CEMENT PLANT KILN AGE

Decreased capacity and increased demand resulted in high capacity utilization and regional shortages. This time, however, the margin on sales, which had slowly climbed to 4 to 5 percent was restrained by price controls (Mongoven, 1977). The price controls put into effect in 1971 used the late 1960s as a base period. This period was particularly poor financially for the industry and the effect was to postpone new construction during what should have been a particularly profitable period. The cement industry was one of the first industries to have controls removed in 1973. When the controls were removed, the price of cement jumped 14 percent and new capacity construction was initiated. Shortly thereafter, the U.S. entered a severe recession which left the cement industry with excess capacity.

By 1975, production had fallen to 64.5 million Mg while capacity had grown to 92.3 million Mg for a net of 70 percent utilization of clinker production capacity (Bureau of Mines, 1975). With excess capacity came low profit margins again and a lack of investment capital. Recent expansion has accompanied the rapid growth in the construction industry, but the construction industry can increase demand for cement much faster than the cement industry can increase capacity. Parts of the U.S. are already seeing cement shortages, particularly in the West. The cement industry, however, is wary of increasing capacity as it has done in the past, only to discover that the excessive demand for cement was a short-term phenomenon.

As shown in Figure 6-2, the Bureau of Mines projections for the early 1980s indicate a possibility of high capacity utilization and possibly regional shortages that usually accompany this trend. Some of this effect is already being felt, i.e., East Coast cement plants are operating at 60 to 65 percent capacity while some West Coast plants are operating at 100 percent capacity (Business Week, 1977). Two interesting details are that East Coast manufacturers are receiving as low as $28/ton while West Coast manufacturers are receiving as much as $53/ton for an identical product (Business Week, 1977). Secondly, although the demand is greater in EPA Region IX, over 50 percent of the capacity completed between 1972 and 1978 was in EPA Regions IV and V (7.4 percent in Region IX) (Portland Cement Association, 1978). Also, the projected future growth announced by the cement industry for 1978 through 1981 indicates less than 30 percent of new kiln capacity will be built in EPA Regions IX and X.

Table 6-1 shows the current and projected distribution of cement production capacity in the U.S. as of November 15, 1978. According to the Portland Cement Association figures, five new plants will be completed by 1981, with a combined capacity of 39 million Mg per year. Table 6-2 shows all the changes in future cement plant capacity changes announced by the cement industry. These announcements indicate an anticipated capacity increase of 2.3 million Mg/year in EPA Regions IX and X. This is 30 percent of the total capacity increase of 7.8 million Mg/year of clinker expected by year-end 1981.

TABLE 6-1

PORTLAND CEMENT CLINKER PRODUCTION CAPACITY

EPA Region	Clinker Capacity[b] (10^3 Mg/yr)	New Kilns 1972-1978[a] No.	New Kilns 1972-1978[a] Capacity (10^3 Mg/yr)[b]	Announced Growth[c] No.	Announced Growth[c] Capacity (10^3 Mg/yr)	Year[a]
I	None	None	-	None	-	-
II	4,248	1 Dry	490	None	-	-
III	12,159	3 Dry	1,602	None	-	-
IV	14,852	7 Dry	3,883	1 Dry[d]	100	79
		4 Wet	1,744	1 Dry	1,361	81
V	13,337	9 Dry	4,215	1 Dry[d]	518	80
VI	11,889	2 Dry	753	1 Dry	499	79
		3 Wet	785	2 Dry[d]	236	79
				1 Dry	726	80
				1 Dry[d]	205	80
				1 Dry	907	NA
VII	10,431	4 Dry	1,123	1 Dry	131	78
				1 Dry	603	80
VIII	3,942	1 Dry	509	1 Dry	122	79
		3 Wet	863	1 Wet	81	79
IX	11,789	2 Dry	720	3 Dry	483	79
		1 Wet	441	3 Dry[d]	1,406	NA
X	2,333	None	-	1 Dry	454	79
TOTAL	84,980	29 Dry	13,295	19 Dry	7,751	
		11 Wet	3,833	1 Wet	81	

NA = Not Announced

[a] Completion Year
[b] As of December 31, 1977
[c] As of November 15, 1978
[d] New plant

Source: Portland Cement Assn., 1978.

TABLE 6-2

ANNOUNCED CEMENT/CLINKER CAPACITY CHANGES
AS OF NOVEMBER 15, 1978

Year	Plant Name	Location	Process	Capacity (10^3 Mg/yr) From	To	Difference
1978	Lehigh	Mason City, IA	Dry	549	680	131
				SUBTOTAL 1978		+131
1979	Oregon Portland	Durkee, OR	Dry	--	454	454
	Texas Industries	Hunter, TX	Dry	--	499	499
	Amcord	Oro Grande, CA	Dry	1041	1247	206
	Ideal	Boettcher, CO	Dry	295	417	122
	Ideal	Knoxville, TN	Dry	426	526	100
	Kaiser	San Antonio, TX	Dry	713	713	0
	Lone Star	Davenport, CA	Dry	358	635	277
	OKC	Pryor, OK	Dry	390	626	236
	Utah Portland	Salt Lake City, UT	Wet	318	399	81
				SUBTOTAL 1979		+1975
1980	General Portland	New Braunfels, TX	Dry	--	726	726
	Kaiser	Permanente, CA	Dry	1450	1450	0
	Marquette	Cape Girardeau, MO	Dry	304	907	603
	Medusa	Charlevoix, MI	Dry	698	1216	518
	Southwestern	Odessa, TX	Dry	249	454	205
				SUBTOTAL 1980		+2052
1981	Ideal	Theodore, AL	Dry	--	1361	1361
				SUBTOTAL 1981		+1361
No Date Given	Lonestar	Georgetown, TX	Dry	--	907	907
	California Portland	Mojave, CA	Dry	1043	1996	953
	Flintkote	Redding & San Andreas, CA	D-W	816	1270	453
	Kaiser	Lucerne Valley, CA	Wet	907	907	0
				SUBTOTAL		+2313
			TOTAL CHANGE IN DRY PROCESS			+7751
			TOTAL CHANGE IN WET PROCESS			81
			GRAND TOTAL PROCESS CHANGE THROUGH 1981			+7832

Source: Portland Cement Association, 1978a.

The effects of pollution abatement requirements on the cement industry have been mentioned previously. Rutledge et al. (1978) hypothesized that air pollution regulations contribute to more industrial closings than water pollution requirements. In their survey, they found that air pollution problems were cited as a contributory factor in permanent closings almost twice as often as water pollution problems. Daugherty and Wist (1974) reported that in the years prior to 1974, 15 cement plants were shut down chiefly due to environmental pressures. Plant closures are expected to continue as new, energy-efficient, cement plants are built. These new plants will often replace older, obsolete equipment in an air pollution and cost minimizing trade-off situation.

Capital expenditures for air pollution abatement equipment in the U.S. decreased in 1977 (Rutledge et al., 1978). In the portland cement industry, pollution control expenditures average about 10 percent of the total construction costs for a new plant (Mongoven, 1977). This is a decrease from the estimated 13 percent that EPA indicated in 1971 in the original background study for the proposed new-source performance standards.

The Council on Wage and Price Control (Mongoven, 1977) came to the following conclusion concerning the effect of pollution abatement on the cement industry:

> A reduction in the rate of increase in operating costs from 6 percent to 5 percent will do more to encourage the building of new cement capacity than would the reduction in the cost of a

new plant (by eliminating the need for pollution control devices). This result suggests that an effective macroeconomic stabilization policy could be the most important step in reducing the possibility of long run material shortages.

Have the NSPS for Portland Cement Plants stifled new capital investment? The Council on Wage and Price Stability (Mongoven, 1977) concluded that:

> ...These figures indicate that the added pollution control costs do change the way a firm would consider a new investment decision by making larger price increases necessary for the expenditures to be committed. This does not mean that the imposition of these controls has necessarily caused any reduction in new capacity expenditures in the cement industry. However, this analysis does leave open the possibility that an investment decision could be changed for a marginal plant because of pollution control costs. (Particularly a plant selling cement for $40 per ton and using a 12 percent rate of return).

Since cement is already selling for as high as $53 per ton on the West Coast, it is very likely that capital investment will not be stifled by pollution control expenditures.

In conclusion, the following remarks summarize the status of the cement industry:

- Cement production is a regional industry caused by the high-volume/low-value nature of the product and high transportation costs.
- The industry has suffered high excess capacity periods and low profits that have stifled capital investment.
- Pollution abatement requirements may affect capital investment decisions, however, minor changes in future operating costs will have a more significant effect.
- The current price of cement is sufficient to stimulate new capacity construction, regardless of the effect of present pollution abatement requirements.

6.2 Excessive Emissions During Cement Kiln Startup

The NSPS specifically exempt affected facilities from the standard during periods of startup, shutdown, or malfunction. If a cement kiln is permitted to operate uncontrolled during the start-up period, emissions may be estimated as 122 kg/Mg feed (dry process) and 114 kg/Mg feed (wet process) (EPA, 1977) and greater than 60 percent opacity (PEDCo Environmental, Inc. 1978) for 4-24 hours. Although startup periods are estimated to be only 2 percent of total operating time, controlled emissions are so low that startup emissions are a significant amount of the total kiln emissions.

During kiln startup, the temperature of the kiln is raised slowly to reduce the loss of refractory lining. While it is warming up, a number of combustible materials will be present in the exhaust stream. These include carbon monoxide as well as unburned fuel. Under normal conditions, the emission controls are not bypassed during periods of startup and shutdown and cyclones and fabric filters are not affected by the exhaust stream composition during these periods. However, due to the nature of electrostatic precipitator operations, the internal arcing presents a fire and explosion hazard in the presence of combustibles. For this reason ESPs are generally shut down during kiln startup and provide only settling chamber control of particulate emissions. Approximately 40 percent of present NSPS affected facilities use ESPs for kiln emission control.

A common operating practice during startup is to gradually energize the ESP once the inlet gas temperature reaches 177°C (350°F).

The ESP is energized gradually to prevent damage to insulators. In the case of shutdown, the ESP is left energized so that excessive emissions are not a problem.

There is little that can be done to reduce emissions during cement kiln startup and shutdown when an ESP is used as the control. The excessive emissions are a result of the limitations of the kiln and ESP in that the kiln cannot be heated rapidly and the ESP cannot be activated in the presence of combustibles. The following suggestions were made by PEDCo Environmental, Inc. (1978) as means of minimizing the excessive emissions:

1. Use oil or gas fired preheating on coal fired kilns, then switch to coal after the ESP has been energized.

2. Use sensors to monitor the ESP inlet gas stream for combustible gases. As soon as the gas stream is safe, energize the ESP.

3. Use a cyclone before the ESP.

6.3 Raw-Mill Bypass

An issue was raised by EPA Region IV personnel about compliance during periods of excessive emissions caused by bypassing the raw-mill on a dry process kiln. Usually the raw-mill feeds raw meal (dry kiln feed material) to storage from which the kiln is fed. Kiln exhaust passes through the storage and raw-mill to conserve energy by preheating the feed. A side benefit of doing this is a reduction in particulate matter loading in the inlet gas stream to the emission control device.

However, when the raw-mill produces raw meal at a faster rate than the kiln is being fed, it must be shut down until the kiln catches up. At this time, the kiln exhaust stream bypasses the raw-mill and goes directly to the emission control device. The increased loading to the control device yields increased emissions to the atmosphere which in turn may make the facility out of compliance.

The issue was resolved in that raw-mill bypass is considered a normally accepted operating procedure in the industry and would not constitute an upset or malfunction operation, thereby qualifying for an exemption from the NSPS.

6.4 Use of Alternate Fuels

Most of the NSPS affected facilities use coal as fuel to fire the kiln and were tested for compliance while using coal. All but one kiln was found to be in compliance with the standard.

Although one would expect the burning of coal to increase particulate matter loading in the exhaust stream, the fly ash that does not become incorporated into the clinker is not expected to raise emissions to the point that they exceed the standard. It is expected that the environmental effects of converting from oil or gas to coal will be primarily the fugitive dust emissions from the handling and storage of coal (Arthur D. Little, Inc., 1976). Water pollution resulting from rainwater runoff from outdoor coal storage piles must also be controlled.

No major air pollution effects are anticipated from the conversion to coal from oil and gas.

6.5 Gaseous Emissions

The exhaust streams from cement kilns and clinker coolers contain a number of gaseous species in addition to the particulate matter. The vaporized alkaline salts that condense to a fume and are removed with mineral dust particles have already been discussed. The following paragraphs discuss those emissions of carbon monoxide, sulfur oxides and nitrogen oxides which remain in a gaseous state and are therefore uncontrolled. Fluorides, hydrocarbons and hydrogen sulfide may also be emitted.

6.5.1 Carbon Monoxide

Carbon monoxide emissions are generally negligible due to the excess air present in the kiln. A typical analysis of the kiln exhaust gas would have 0 to 2 volume percent carbon monoxide (Daugherty and Wist, 1974).

6.5.2 Fluorine

Fluorine can be released in the kiln from the raw materials and fuel during the formation of clinker. Tests performed on the cleaned gas from 11 cement kilns found no gaseous fluorides (Daugherty and Wist, 1974). This was expected since calcium fluoride is produced in the presence of excess calcium oxide and the ESP or baghouse is capable of removing the solid calcium fluoride.

6.5.3 Hydrocarbons

Hydrocarbons, principally aldehydes, can result from the discharge of the products of incomplete fuel combustion. This would

ordinarily only occur during startup or malfunction. Data collected by Daugherty and Wist (1974) indicate an annual emission of 54 Mg of hydrocarbons from a 444,000 Mg per year dry process plant and only 34 Mg from a 298,000 Mg/yr wet process plant.

6.5.4 Hydrogen Sulfide

Hydrogen sulfide and other odiferous sulfides can be emitted from a cement plant if certain raw materials such as marl, clay, shale, and marine shells are used in a wet process kiln. It is also possible that a kiln operated under reducing conditions, rather than the usual excess air conditions, can reduce sulfur oxides to polysulfides and hydrogen sulfide (Daugherty and Wist, 1974). Establishing excess air conditions by reducing the fuel supply and increasing the air supply will control this.

6.5.5 Nitrogen Oxides

Cement kilns are a very large source of nitrogen oxides (NO_x) emissions. The EPA (1974) estimates NO_x emissions as 1.3 kg/Mg of cement produced. Since 71.4 million Mg of portland cement were produced in 1977 (Bureau of Mines, 1978), an estimated 93,000 Mg of NO_x were emitted by portland cement plants that year. According to the 1975 National Emissions Report, Mineral Products is the second largest industrial process source of NO_x emissions. In addition, data presented by Daugherty and Wist (1974) show NO_x emissions ranging from 150 to 1050 ppm.

Nitrogen oxides are formed in the high temperature burning zone of the cement kiln. This portion of the kiln is maintained at temperatures up to 1650°C and under oxidative conditions. The generation of NO_x in the kiln cannot be avoided because use of any other nonnitrogen containing oxidizing gas would be prohibitively expensive.

The main factors that result in the production of NO_x are the flame and kiln temperature, the residence time that combustion gases remain at this temperature, the rate of cooling of these gases, and the quantity of excess air in the flame. Control of these factors may permit the operator to sharply reduce the emission of NO_x, but at the present time there is no control equipment in cement plants for NO_x emissions.

It is reported that use of a flash calciner in a suspension preheater will reduce the NO_x emitted per ton of cement. This occurs because the fuel burned in the calciner is at a lower temperature that does not favor NO_x formation. The fuel burned in the calciner reduces the quantity of fuel that must be burned in the kiln as well as reducing the length of the kiln (shortening residence time) required for clinker formation, thus reducing NO_x formation.

6.5.6 Sulfur Oxides

Sulfur oxide (SO_x) emissions from cement kilns are essentially all sulfur dioxide (SO_2) from burning raw meal in the kiln. The burned fuel and the raw meal both contribute to the total SO_2

generated. However, very little of the SO_2 generated is actually emitted into the atmosphere. As the SO_2 is generated, it comes into direct contact with calcium oxide and alkaline oxides already formed in the kiln. Approximately 75 percent of the SO_2 is sorbed on the oxide particles and eventually is incorporated in the clinker (Ketels et al., 1976). In addition, 50 percent of the remaining SO_2 is removed by sorption in a fabric filter baghouse by the same mechanism.

The uncontrolled emission of SO_2 is estimated by EPA (1977) as 5.1 kg/Mg of cement produced plus the SO_2 contributed by the fuel: 2.15 kg/Mg for oil and 3.45 kg/Mg for coal. If all cement plants were converted to use 3 percent sulfur coal, in a kiln controlled by a baghouse, then an estimated 186,000 Mg of SO_2 would have been emitted during 1977. This is a very high estimate and does not take into consideration the following factors:

1. Sulfur content of the kiln feed can vary widely
2. Sorption of SO_2 will be affected by the availability of calcium and alkaline oxides which will vary with the kiln feed
3. The type of process--the mechanism of a suspension preheater--should permit greater sorption of SO_2.

Only one NSPS cement plant was tested for SO_2 emissions. The Louisville Cement Plant at Speed, Indiana, showed SO_2 emissions of 0.716 kg/Mg feed with the mill on and 1.517 kg/Mg feed with the mill off. These measurements are substantially less than the EPA estimate of uncontrolled emissions mentioned above.

7.0 FINDINGS AND RECOMMENDATIONS

The primary objective of this report has been to assess the need for revision of the existing NSPS for portland cement plants. The particulate matter standard is reviewed below. The existing opacity standard was thoroughly reviewed in the report to the U.S. District Court of Appeals for the District of Columbia in answer to their remand of the standard to EPA.

7.1 Findings

7.1.1 Process Emission Control Technology

- The current best demonstrated control technology for particulate matter emissions has changed since the original standard was promulgated only in that kilns equipped with ESPs are capable of meeting the standard. Fabric filter baghouses continue to share the position as a best control technology since the original standard was based on this type of control. No new developments have occurred in either of these technologies to substantiate a reduction in the allowable emissions from either kilns or clinker coolers.

- Although the measured kiln emissions were as low as 0.013 kg/Mg feed, there was no indication that this level could be maintained or that other units testing as high as 0.142 kg/Mg feed could emit less. There was no correlation between kiln size, control technology, wet or dry process, and emission rate.

- The range of emission rates for clinker coolers (0.005 kg/Mg to 0.43 kg/Mg feed) also showed no correlation with known variables or that these levels could be maintained with age.

- Both the kiln and clinker coolers are presently required to reduce emissions greater than 99 percent.

7.1.2 Economic Considerations

- The cement industry is a capital and energy intensive industry that has had difficulty attracting capital investment due to low profitability in past years.

- The cost of pollution controls to the cement industry is approximately 10 percent of capital investment at the present time.

- The U.S. is currently entering a period of cement capacity shortage and increased pollution abatement costs will have an effect on investment decisions.

7.1.3 Gaseous Emissions

- The emissions of carbon monoxide, hydrocarbons, fluorides, and hydrogen sulfide are not significant.

- Sulfur dioxide emissions are controlled substantially (nearly 90 percent) already, without a standard. It is not known if emissions can be reduced beyond that level.

- Nitrogen oxides are emitted from cement kilns in large quantities. There are no known controls for these emissions. Possible methods of reducing the quantity of NO_x emitted have not been tested.

7.2 Recommendations

7.2.1 Opacity NSPS

There is no justification for changing the opacity standard for any portion of the portland cement plant.

7.2.2 Particulate Matter NSPS

There is no justification for changing the particulate matter standard for either the kiln or clinker cooler because:

- The best demonstrated control technologies, ESP and/or baghouse, are currently in use at all new portland cement plants.

- The current standard requires greater than 99 percent reduction in emissions, which is the maximum for these control technologies.

7.2.3 Gaseous Emissions

It is recommended that a monitoring program be initiated to determine the actual emission rate of SO_2 and NO_x from portland cement kilns.

It is further recommended that research and development be conducted to find means for reducing NO_x emissions.

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